

NFPA®

484

**Standard for
Combustible Metals**

2019



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NFPA® 484

Standard for

Combustible Metals

2019 Edition

This edition of NFPA 484, *Standard for Combustible Metals*, was prepared by the Technical Committee on Combustible Metals and Metal Dusts and released by the Correlating Committee on Combustible Dusts. It was issued by the Standards Council on May 4, 2018, with an effective date of May 24, 2018, and supersedes all previous editions.

This document has been amended by one or more Tentative Interim Amendments (TIAs) and/or Errata. See “Codes & Standards” at www.nfpa.org for more information.

This edition of NFPA 484 was approved as an American National Standard on May 24, 2018.

Origin and Development of NFPA 484

The 2002 edition of NFPA 484, then titled *Standard for Combustible Metals, Metal Powders, and Metal Dusts*, was a comprehensive combustible-metal fire safety document. It was created by taking the requirements of the metals standards NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders*; NFPA 481, *Standard for the Production, Processing, Handling, and Storage of Titanium*; NFPA 482, *Standard for the Production, Processing, Handling, and Storage of Zirconium*; NFPA 485, *Standard for the Storage, Handling, Processing, and Use of Lithium Metal*; NFPA 65, *Standard for the Processing and Finishing of Aluminum*; and NFPA 651, *Standard for the Machining and Finishing of Aluminum and the Production and Handling of Aluminum Powders*, and making them into individual chapters in NFPA 484. Chapter 10 was written to address combustible metals not covered by one of the metal-specific chapters. Additionally, a metal-specific chapter was written for tantalum because of its increased use. Thus, NFPA 484 provided safety requirements, including processing, storage, handling, dust collection, housekeeping, and fire protection, for all combustible metals.

The 2006 edition of NFPA 484, *Standard for Combustible Metals*, contained several major changes, including a new title. A new chapter, Chapter 4, gave test requirements for classifying a material as a combustible metal. Other new chapters were Chapter 5, which addressed alkali metals; Chapter 8, which addressed niobium; and Chapter 13, which consolidated the fire protection requirements given in Chapters 5 through 12.

The 2009 edition of NFPA 484 contained the following changes:

- (1) Addition of a new Chapter 14, Combustible Metal Recycling Facilities
- (2) Addition of thresholds in Table 1.1.9, for applicability of the document; before this change the standard applied to any amount of a combustible metal
- (3) Updates to the recommended suppression materials in Table A.13.3.3

The 2012 edition of NFPA 484 contained the following changes:

- (1) A unified format was applied for chapter-to-chapter consistency for the individual combustible metals in the document.
- (2) New definitions were added for dust explosion and dust flash-fire hazard area and a number of particular forms, including metal dust, fines, superfines, ultrafines, flakes, paste, and ribbon. A definition for screening test was added. The committee clarified when the standard would apply rather than when the standard would not apply. New information was included in Chapter 16 to clarify the testing and classification of potentially combustible metals.
- (3) Management of change requirements was added to chapters where it had not been previously identified as a requirement.

- (4) New information was included about wet dust collection systems and about housekeeping, an important issue for the prevention of fires and explosions. Personal protective equipment (PPE) requirements were identified.
- (5) Chapter 15, Fire Prevention, Fire Protection, and Emergency Response, remained retroactive for all of the specific metal chapters and for the general metal chapter.
- (6) Chapter 16, Combustible Metal Recycling Facilities, was retroactive. Information was added to address emergency response requirements.
- (7) Hazard analysis requirements were applicable to all metal chapters.
- (8) A new chapter on performance-based design was added.

The 2015 edition of NFPA 484 revised a provision in Chapter 1 that established a framework for the protection of mixtures of metals and other combustible dusts and included revised definitions in Chapter 3. Chapter 4 included revised procedures for material characterization and determining combustibility and explosibility for metal dusts. As part of those requirements, test data or historical data were permitted to be used. Chapter 5 included requirements for management systems elements, such as management of change, hazard analysis, and personal protective equipment. As part of an effort to consolidate fundamental requirements within dedicated chapters, ignition control sources such as hot work and static electricity were moved from Chapter 6 to Chapter 8 and retitled Control of Ignition Sources. Chapter 6 included new requirements on emergency response and preparedness. In Chapter 7, the committee established a threshold for fugitive dust accumulations, which was used to trigger specific requirements related to dust hazard control. Chapter 9 was modified to include requirements for pneumatic conveying. The committee also modified Chapters 11 through 18 by moving requirements common for all the metal types (such as PPE, management of change, dust collection, ignition sources, and hazard analysis) to one of the fundamental chapters (Chapters 4 through 9). The committee added acceptance criteria to Chapter 19 for metal recycling.

The 2019 edition of NFPA 484 is a complete reorganization of the document. Many of the changes were made to align the document with NFPA 652, the new *Standard on the Fundamental of Combustible Dust*. A new Chapter 7 was added on Dust Hazard Analysis. Chapter 4, General, was added to include material on objectives and compliance options to align with NFPA 652. Chapter 4 now includes requirements on Management of Change and Personnel Protective Equipment. New chapters are added to the document on Nanometals (Chapter 12) and Additive Manufacturing (Chapter 13) to reflect emerging technologies and issues in the metals industry. Chapter 11, Powder and Dust Collection and Centralized Vacuum Systems, is completely rewritten to provide clarity for the users. Chapter 15, Legacy Metals, consolidates the common requirements for aluminum, magnesium, niobium, tantalum, titanium, zirconium, and hafnium into a single location. Note that material that is specific to one of these metals remains in the metal-specific chapters.

In addition to the above changes, definitions in Chapter 3 are reviewed and updated to correlate with those in NFPA 652, the fundamentals document. Where requirements in the code are retroactive, statements indicate this clearly to the user. Material is added to the scope in Chapter 1 to clarify the application of the standard to mixtures of metals and other combustible nonmetal dusts. Changes in Chapter 8 clarify and strengthen the requirements regarding static electricity. Changes are also made to the requirements for electrical area classification, referring to *NFPA 70®*, *National Electrical Code®*, but clarify that the committee does not agree with the definition of combustible dust found in *NFPA 70*. The committee also clarifies that the zone classification system is not to be used for metal dusts.

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Committee Scope: This Committee shall have primary responsibility for documents on the hazard identification, prevention, control, and extinguishment of fires and explosions in the design, construction, installation, operation, and maintenance of facilities and systems used in manufacturing, processing, recycling, handling, conveying, or storing combustible particulate solids, combustible metals, or hybrid mixtures.

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Committee Scope: This Committee shall have primary responsibility for documents on safeguards against fire and explosion in the manufacturing, processing, handling, and storage of combustible metals, powders, and dusts.

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NFPA 484

Standard for

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2019 Edition

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Information on referenced publications can be found in Chapter 2 and Annex J.

Chapter 1 Administration

1.1* Scope. This standard provides requirements for the production, processing, finishing, handling, recycling, storage, and use of all metals and alloys that are in a form that is capable of combustion or explosion.

1.1.1* The procedures in Chapter 5 shall be used to determine whether a metal is in a noncombustible form.

1.1.2 Combustible Metal Powder or Dust.

1.1.2.1 This standard provides requirements for operations where metal or metal alloys are subjected to processing or finishing operations that produce combustible powder or dust.

N 1.1.2.2* This standard shall apply to the storage or use of ignitable fibers/flyings, specifically with regard to fire hazards.

1.1.2.3 Operations where metal or metal alloys are subjected to processing or finishing operations that produce combustible powder or dust shall include, but shall not be limited to, machining, sawing, grinding, buffing, and polishing.

1.1.3* Metals, metal alloy parts, and those materials, including scrap and mixtures, shall be subject to the requirements of the metal whose combustion characteristics they most closely match.

Δ 1.1.4 Metals, metal alloy parts, and those materials and mixtures, including scrap, not covered by a specific metal chapter, are subject to the requirements of Chapter 16.

1.1.5 Materials submitted for recycling or waste disposal shall be subject to the requirements of Chapter 17.

1.1.6* This standard provides requirements for mixtures that contain metals exhibiting combustion characteristics of metals covered by this standard. (See 5.1.4 for additional information on testing and characterization.)

1.1.6.1 Metal only mixtures shall be subject to the requirements of this standard.

Δ 1.1.6.2* Metal-containing mixtures that also contain combustible nonmetal dusts shall be permitted to be excluded from this standard and protected according to NFPA 652 and NFPA 654 or another NFPA industry- or commodity-specific standard, if by testing it is established that the mixture meets all of the following criteria:

- (1) It has been demonstrated that mixture fires can be controlled safely and effectively with Class ABC fire-extinguishing agents.
- (2) It has been demonstrated that mixture fires can be controlled safely and effectively with water.
- (3) The material is not a UN Class 4.3 solid as tested using UN Class 4.3 water reactivity test methods.
- (4) It has been demonstrated that the volume resistivity is greater than 1 M ohm-m.
- (5) It is not a metal/metal-oxide mixture (e.g., thermite).

1.1.7* This standard shall not apply to the transportation of metals in any form on public highways and waterways or by air or rail.

1.1.8 This standard shall not apply to the primary production of aluminum, magnesium, and lithium.

1.1.9 This standard shall apply to laboratories that handle or use more than 0.23 kg (½ lb) of alkali metals or 0.907 kg (2 lb) aggregate of other combustible metals, excluding alkali metals.

N 1.1.9.1 Applicability thresholds for storage in laboratories shall follow the appropriate occupancy classification as designated by NFPA 45 and threshold quantities per Table 1.1.11.

1.1.10 All alkali metals and metals that are in a form that is water reactive shall be subject to this standard.

1.1.11* If the quantity of a combustible metal listed in Table 1.1.11 is exceeded in an occupancy, the requirements of this document shall apply.

1.2 Purpose. The objective of this standard shall be to minimize the occurrence of, and resulting damage from, fire or explosion in areas where combustible metals or metal dusts are produced, processed, finished, handled, stored, and used.

Table 1.1.11 Applicability Thresholds by Occupancy

Occupancy Class (as defined in NFPA 5000)	Threshold Quantity (kg)	Threshold Quantity (lb)
Assembly	0.454	1
Educational	0.23 kg of alkali metals or 0.907 aggregate of other combustible metals, excluding alkali metals	½ lb of alkali metals or 2 aggregate of other combustible metals, excluding alkali metals
Day care	Not permitted	Not permitted
Health care	0.907	2
Ambulatory health care	0.907	2
Detention and correctional	Not permitted	Not permitted
Residential	0.907	2
Residential board and care	Not permitted	Not permitted
Mercantile	0.907	2
Business	4.535	10 for storage; 0 for use and handling
Industrial	2.268	5
Storage	22.675	50

1.3 Application.

1.3.1 The provisions of this document shall be considered necessary to provide a reasonable level of protection from loss of life and property from fire and explosion.

1.3.2 The provisions of this document shall reflect situations and the state of the art prevalent at the time the standard was issued.

1.3.3 A hazard assessment shall be performed to resolve any conflicts between the requirements of this standard and any other NFPA code or standard.

1.4 Conflicts.

1.4.1 Where a requirement specified in this industry-specific standard differs from a requirement specified in NFPA 652, the requirement in this standard shall be permitted to be used instead.

1.4.2 Where a requirement specified in this standard specifically prohibits a requirement specified in NFPA 652, the prohibition in this standard shall be applied.

1.5 Retroactivity. The provisions of this standard shall reflect a consensus of what is necessary to provide an acceptable degree of protection from the hazards addressed in this standard at the time the standard was issued.

1.5.1 Unless otherwise specified, the provisions of this standard shall not apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the standard.

1.5.2* Where specified, the provisions of this standard shall be retroactive.

1.5.3 In those cases where the authority having jurisdiction determines that the existing situation presents an unacceptable degree of risk, the authority having jurisdiction shall be permitted to apply retroactively any portions of this standard deemed appropriate.

1.5.4 The retroactive requirements of this standard shall be permitted to be modified if their application clearly would be impractical in the judgment of the authority having jurisdiction, and only where it is clearly evident that a reasonable degree of safety is provided.

1.6 Units and Formulas.

1.6.1 SI Units. Metric units of measurement in this standard shall be in accordance with the modernized metric system known as the International System of Units (SI).

1.6.2* Primary and Equivalent Values. If a value for a measurement as given in this standard is followed by an equivalent value in other units, the first stated value shall be regarded as the requirement.

1.6.3 Conversion Procedure. SI units shall be converted by multiplying the quantity by the conversion factor and then rounding the result to the appropriate number of significant digits.

1.7 Equivalency. Nothing in this standard shall be intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard, provided technical documentation is made available to the authority having jurisdiction to demonstrate equivalency, and the system, method, or device is approved for the intended purpose.

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 1, *Fire Code*, 2018 edition.

NFPA 2, *Hydrogen Technologies Code*, 2016 edition.

NFPA 10, *Standard for Portable Fire Extinguishers*, 2018 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 2019 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 2018 edition.

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials*, 2018 edition.

NFPA 34, *Standard for Dipping, Coating, and Printing Processes Using Flammable or Combustible Liquids*, 2018 edition.

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, 2015 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*, 2019 edition.

NFPA 54, *National Fuel Gas Code*, 2018 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, 2018 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 2014 edition.

NFPA 70®, *National Electrical Code®*, 2017 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 2019 edition.

NFPA 80, *Standard for Fire Doors and Other Opening Protectives*, 2019 edition.

NFPA 86, *Standard for Ovens and Furnaces*, 2019 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids*, 2015 edition.

NFPA 101®, *Life Safety Code*®, 2018 edition.

NFPA 220, *Standard on Types of Building Construction*, 2018 edition.

NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls*, 2018 edition.

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*, 2017 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations*, 2018 edition.

NFPA 600, *Standard on Facility Fire Brigades*, 2015 edition.

NFPA 652, *Standard on the Fundamentals of Combustible Dust*, 2019 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, 2017 edition.

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, 2017 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems*, 2017 edition.

NFPA 1081, *Standard for Industrial Fire Brigade Member Professional Qualifications*, 2018 edition.

NFPA 2112, *Standard on Flame-Resistant Clothing for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire*, 2018 edition.

NFPA 2113, *Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire*, 2015 edition.

NFPA 5000®, *Building Construction and Safety Code*®, 2018 edition.

2.3 Other Publications.

▲ **2.3.1 ASME Publications.** ASME International, Two Park Avenue, New York, NY 10016-5990.

ASME B31.3, *Process Piping*, 2016.

▲ **2.3.2 ASTM Publications.** ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM E11, *Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves*, 2017.

ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, 2016a.

ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, 2012a.

ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, 2003, reapproved 2013.

ASTM F1002, *Standard Performance Specification for Protective Clothing and Materials for Use by Workers Exposed to Specific Molten Substances and Related Thermal Hazards*, 2015.

■ **2.3.3 ISA Publications.** International Society of Automation, 67 T. W. Alexander Drive, P.O. Box 12277, Research Triangle Park, NC 27709.

ISA 84.00.01, *Functional Safety: Application of Safety Instrumented Systems for the Process Industry Sector*, 2004.

2.3.4 UN Publications. United Nations Publications, Room DC2-853, 2 UN Plaza, New York, NY 10017.

UN Recommendations on the Transport of Dangerous Goods: Manual of Tests and Criteria, 5th edition, 2009.

▲ 2.3.5 Other Publications.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

▲ 2.4 References for Extracts in Mandatory Sections.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*, 2019 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, 2018 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 2014 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids*, 2015 edition.

NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls*, 2018 edition.

NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 2021 edition.

NFPA 652, *Standard on the Fundamentals of Combustible Dust*, 2019 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, 2017 edition.

NFPA 921, *Guide for Fire and Explosion Investigations*, 2017 edition.

NFPA 1250, *Recommended Practice in Fire and Emergency Service Organization Risk Management*, 2015 edition.

NFPA 1451, *Standard for a Fire and Emergency Service Vehicle Operations Training Program*, 2018 edition.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary*, 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

3.2.4* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.5 Shall. Indicates a mandatory requirement.

3.2.6 Should. Indicates a recommendation or that which is advised but not required.

3.2.7 Standard. An NFPA Standard, the main text of which contains only mandatory provisions using the word “shall” to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA Manuals of Style. When used in a generic sense, such as in the phrase “standards development process” or “standards development activities,” the term “standards” includes all NFPA Standards, including Codes, Standards, Recommended Practices, and Guides.

3.3 General Definitions.

N 3.3.1* Air-Material Separator (AMS). A device designed to separate the conveying air from the material being conveyed. [654, 2017]

N 3.3.1.1 Enclosureless AMS. An air-material separator designed to separate the conveying air from the material being conveyed where the filter media are not enclosed or in a container. [652, 2019]

N 3.3.2* Air-Moving Device (AMD). A power-driven fan, blower, or other device that establishes an airflow by moving a given volume of air or gas per unit time. [652, 2019]

3.3.3 Alkali Metals. See 3.3.45.1.

3.3.4 Aluminum Paste. Aluminum flake pigment homogeneously incorporated in a solid or liquid carrier in such a way so as to have a nonflowing product without a free-flowing liquid.

3.3.5 Aluminum Powder. See 3.3.56.3.

N 3.3.6 Bonding. For the purpose of controlling static electric hazards, the process of connecting two or more conductive objects by means of a conductor so that they are at the same electrical potential but not necessarily at the same potential as the earth. [652, 2019]

3.3.7 Castings. An object or finished shape obtained by solidification of a substance in a mold.

3.3.7.1* Heavy Casting. Castings greater than 11.3 kg (25 lb) with walls of large cross-sectional dimensions [at least 6.4 mm (¼ in.)].

N 3.3.8* Centralized Vacuum Cleaning System. A fixed-pipe system utilizing variable-volume negative-pressure (i.e., vacuum) air flows from remotely located hose connection stations to allow the removal of dust accumulations from surfa-

ces and conveying those dusts to an air-material separator (AMS). [652, 2019]

3.3.9* Chips. Particles produced from a cutting or machining operation that are not oxidized and that are not diluted by noncombustible materials.

N 3.3.10* Combustible Dust. A finely divided combustible particulate solid, including combustible fibers/flyings, that presents a flash-fire hazard or explosion hazard when suspended in air or the process-specific oxidizing medium over a range of concentrations. [652, 2019]

N 3.3.11* Combustible Fibers/Flyings. Fibers/flyings, where any dimension is greater than 500 µm in nominal size, which can form an explosible mixture when suspended in air at standard atmospheric pressure and temperature. [499, 2021]

3.3.12 Combustible Metal. See 3.3.45.2.

Δ 3.3.12.1* Combustible Metal Dust. A combustible particulate metal, including combustible fibers/flyings, that presents a fire or explosion hazard when suspended in air or the process-specific oxidizing medium over a range of concentrations.

3.3.12.2 Combustible Metal Particulate. See 3.3.12.1, Combustible Metal Dust.

3.3.12.3* Metal Dust. Particulate metal resulting from a solid state secondary processing operation.

N 3.3.13* Combustible Particulate Solid. Any solid material composed of distinct particles or pieces, regardless of size, shape, or chemical composition, that, when processed, stored, or handled in the facility, has the potential to produce a combustible dust. [652, 2019]

N 3.3.14 Compartment. A subdivision of an enclosure. [652, 2019]

3.3.15* Critical Process. A process that has the potential to cause harm to personnel, equipment, structures, or product in the event of an uncontrolled failure.

3.3.16 Deflagration. Propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium. [68, 2018]

3.3.17 Deflagration Hazard Area.

3.3.17.1 Dust Explosion Hazard Area. A room or building volume where an unvented deflagration of the entrainable dust mass can result in a pressure exceeding the strength of the weakest structural element not intended to fail.

3.3.17.2 Dust Flash-Fire Hazard Area. An area where combustible dust accumulation on exposed or concealed surfaces, outside of equipment or containers, can result in personnel injury from thermal dose during a dust deflagration, as well as any areas where dust clouds of a hazardous concentration exist during normal operation. A propagating deflagration yield a flash-fire through the hazard area.

N 3.3.18 Detachment. A hazard management strategy in which the hazard is located in a separate building or an outside area, removed from other structures to be protected by a distance as required by this standard. [654, 2017]

3.3.19 Dryer. A piece of processing equipment using temperature or pressure change to reduce the moisture or volatile content of the material being handled. [654, 2017]

3.3.20 Duct. Pipes, tubes, or other enclosures used for the purpose of pneumatically conveying materials. [91, 2015]

▲ **3.3.21 Dust.** See 3.3.12.1, Combustible Metal Dust.

N **3.3.21.1* Dust Collection System.** A combination of equipment designed to capture, contain, and pneumatically convey fugitive dust to an air-material separator (AMS) in order to remove the dust from the process equipment or surrounding area. [652, 2019]

N **3.3.21.1.1 Dry-Type Dust Collector.** A device that does not use liquid to separate the material being conveyed from the conveying medium, such as cyclones or media collectors.

N **3.3.21.1.2 Wet-Type Dust Collector.** A device that uses liquid to separate the material being conveyed from the conveying medium.

N **3.3.21.2 Dust Deflagration Hazard.** A condition that presents the potential for harm or damage to people, property, or the environment due to the combustion of a sufficient quantity of combustible dust suspended in air or another oxidizing medium. [652, 2019]

N **3.3.21.3 Dust Explosion Hazard.** A dust deflagration hazard in an enclosure that is capable of bursting or rupturing the enclosure due to the development of internal pressure from the deflagration. [652, 2019]

N **3.3.21.4* Dust Hazards Analysis (DHA).** A systematic review to identify and evaluate the potential fire, flash fire, or explosion hazards associated with the presence of one or more combustible particulate solids in a process or facility. [652, 2019]

▲ **3.3.22 Eutectic Reaction. (Reserved)**

N **3.3.23* Explosible.** Capable of propagating a deflagration when dispersed in air or the process-specific oxidizing media. [652, 2019].

3.3.24 Explosion. The bursting or rupture of an enclosure or a container due to the development of internal pressure from a deflagration. [69, 2014]

3.3.25 Fines. The portion of a powder composed of particles that are smaller than 45 microns (U.S. Standard Sieve No. 325); also known as the subsieve size fraction.

3.3.25.1 Superfines. Particles smaller than 10 microns (μm).

3.3.25.2 Ultrafines. Particles with size generally less than 1 micron (μm).

N **3.3.26 Fire Hazard.** Any situation, process, material, or condition that, on the basis of applicable data, can cause a fire or provide a ready fuel supply to augment the spread or intensity of a fire and poses a threat to life or property. [652, 2019]

3.3.27* Fire-Resistive. Meeting the requirements for Type I or Type II construction.

3.3.28 Flake. A flat or scale-like particulate material that is relatively thin with a large aspect ratio.

N **3.3.29* Flash Fire.** A deflagration that spreads through a combustible dust, gas, or vapor cloud without the production of damaging pressure.

N **3.3.30 Fuel Object.** A combustible object or mass of particulate that can serve as a source of fuel for a fire or deflagration; sometimes referred to as a *fuel package*. [652, 2019]

N **3.3.31 Fugitive Dusts.** Dust that escapes from equipment and containers. [652, 2019]

3.3.32 Fugitive Material. See 3.3.42.1.

N **3.3.33 Grounding.** The process of bonding one or more conductive objects to the ground so that all objects are at zero electrical potential; also referred to as *earthing*. [652, 2019]

3.3.34 Handling. Any activity, including processing, that can expose the metal's surface to air or to any other substance capable of reacting with the metal under the conditions of the exposure.

3.3.35 Hazard Analysis. A documented assessment performed by personnel knowledgeable of the specific hazards of the material and that is acceptable to the AHJ.

▲ **3.3.36 Hot Work.** Work involving burning, welding, or a similar operation that is capable of initiating fires or explosions. [51B, 2019]

N **3.3.37* Hybrid Mixture.** An explosible heterogeneous mixture, comprising gas with suspended solid or liquid particulates, in which the total flammable gas concentration is ≥ 10 percent of the lower flammable limit (LFL) and the total suspended particulate concentration is ≥ 10 percent of the minimum explosible concentration (MEC). [68, 2018]

N **3.3.38* Ignitable Fibers/Flyings.** Fibers/flyings where any dimension is greater than 500 μm in nominal size, which are not likely to be in suspension in quantities to produce an explosible mixture, but could produce an ignitable layer fire hazard. [499, 2021]

3.3.39* Incipient-Stage Fire. A fire that is in the initial or beginning stage and that can be controlled or extinguished by portable extinguishers or small amounts of dry extinguishing agents, without the need for protective clothing or breathing apparatus.

N **3.3.40* Industry- or Commodity-Specific Standard.** An NFPA code or standard whose intent as documented within its purpose or scope is to address fire and explosion hazards of a combustible particulate solid. [652, 2019]

N **3.3.41 Limiting Oxidant Concentration (LOC).** The concentration of oxidant in a fuel-oxidant-diluent mixture below which a deflagration cannot occur under specified conditions. [69, 2014]

3.3.42 Material.

3.3.42.1 Fugitive Material. Any particle, regardless of size, that is lost from manufacturing or other processes.

▲ **3.3.42.2* Pyrophoric Material.** A material that ignites upon exposure to air at or below 54.4°C (130°F).

3.3.42.3* Spark-Resistant Material. A material that is not prone to generate impact sparks under conditions of use.

3.3.43 Media Collector. An air-material separator (AMS) that uses filter bags or cartridges for air/gas flow and dust separation.

3.3.44* Mesh Size. The dimensions of a mesh that are specified in ASTM E11, *Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves*.

3.3.45* Metal. Pure metal or alloys having the generally recognized properties of the metal, including the fire or explosion characteristics of the metal in its various forms.

3.3.45.1 Alkali Metals. Cesium, francium, lithium, potassium, rubidium, sodium, and alloys of these metals, such as NaK.

3.3.45.2* Combustible Metal. Any metal composed of distinct particles or pieces, regardless of size, shape, or chemical composition, that will burn.

N 3.3.45.3* Legacy Metals. The metals aluminum, magnesium, niobium, tantalum, titanium, zirconium, and hafnium.

3.3.45.4 Metal Alloy. A multiphase solid that is formed by mixing in the molten state, in which the primary component or matrix phase is a metal and the original composition is retained during size reduction.

3.3.45.5* Metal-Containing Mixture. A physical combination of one or more metals or metal alloys with one or more solid, liquid, or semi-solid chemical elements or compounds.

3.3.46* Minimum Explosible Concentration (MEC). The minimum concentration of a combustible dust suspended in air, measured in mass per unit volume, that will support a deflagration. [654, 2017]

N 3.3.47* Minimum Ignition Energy (MIE). The lowest capacitive spark energy capable of igniting the most ignition-sensitive concentration of a flammable vapor–air mixture or a combustible dust–air mixture as determined by a standard test procedure. [654, 2017]

3.3.48 Mixtures. (Reserved)

N 3.3.49* Nanometal Powder. Any metal powder produced with a characteristic size smaller than 500 nanometers (0.5 μm), which can include powders where only a fraction of the material produced is less than 500 nanometers (0.5 μm). (See also Section 12.2.2.)

3.3.50* Noncombustible. In the form used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat.

3.3.51 Passivation. A controlled process by which a barrier coating is placed on the surface of the metal to inhibit reaction.

3.3.51.1 Oxygen Passivation. A controlled process that exposes the metal powder to oxygen with the goal of forming an oxide of the metal on the particle surface.

3.3.52 Paste. A mixture consisting of a liquid and suspended particles or flakes.

3.3.52.1 Aluminum Paste. Aluminum flake pigment homogeneously incorporated in a solid or liquid carrier in such a

way so as to have a nonflowing product without a free-flowing liquid.

N 3.3.53* Pneumatic Conveying System. An equipment system that transfers a controlled flow of solid particulate material from one location to another using air or other gases as the conveying medium, and that is comprised of the following components: a material feeding device; an enclosed ductwork, piping, or tubing network; an air–material separator; and an air-moving device. [652, 2019]

N 3.3.54 Portable AMS (Dust Collector). A portable machine designed to collect airborne dust produced from a dust-generating operation.

N 3.3.55 Portable Vacuum Cleaner. A portable machine for collecting settled fugitive dust from floors and other surfaces.

3.3.56 Powder. Particles of matter intentionally manufactured to a specific size and shape. Typically, powders are less than 1 millimeter and can be elemental or alloy in composition and regular, irregular, spherical, sponge, granular, dendritic, or nodular in shape.

3.3.56.1* Aluminum Flake Powder. See 3.3.56.3, Aluminum Powder.

3.3.56.2 Aluminum Granular Powder. See 3.3.56.3, Aluminum Powder.

3.3.56.3* Aluminum Powder. Aluminum powder is divided into three broad classifications: atomized, flake, and granules.

3.3.56.4* Combustible Metal Powder. A combustible particulate metal, regardless of particle size or shape, that is an intentional product and will burn as determined by testing conducted in accordance with Chapter 5.

3.3.56.5 Tantalum Powder. Nodular or flake-like tantalum particles that will pass through a 20 mesh screen [850 μm (microns)] as discrete particles or as agglomerates of discrete particles.

3.3.56.5.1 Unrefined Tantalum Powder. Any tantalum powder that contains impurities, such that further refinement is required to produce a tantalum product suitable for commercial use.

3.3.57* Powder Production Plant. Facilities or buildings in which the primary product is powder.

3.3.58 Pyrophoric Material. See 3.3.42.2.

N 3.3.59 Qualified Person. A person who, by possession of a recognized degree, certificate, professional standing, or skill, and who, by knowledge, training, and experience, has demonstrated the ability to deal with problems related to the subject matter, the work, or the project. [1451, 2018]

3.3.60* Recycling. Processing, reprocessing, resizing, sorting, sifting, or staging of scrap materials formerly in the process stream or in use, that no longer serve their original and/or intended purpose, but continue to have resale value.

3.3.61 Replacement-in-Kind. A replacement that satisfies the design specifications of the replaced item. [652, 2019]

3.3.62 Ribbon. A manufactured product or a continuous chip resulting from secondary processing (e.g., boring, grinding, milling, turning, etc.), of a ductile material.

3.3.62.1* Magnesium Ribbon. Magnesium metal that is less than 3.2 mm ($\frac{1}{8}$ in.) in two dimensions or less than 1.3 mm ($\frac{1}{20}$ in.) in single dimension, also considered a powder for the purpose of this standard.

N 3.3.63* Risk Assessment. An assessment of the likelihood, vulnerability, and magnitude of the incidents that could result from exposure to hazards. [1250, 2015]

3.3.64 Screening Test. For the purposes of this standard, a test performed to determine whether a material or mixture exhibits fire-, explosion-, or water-reactivity-related characteristics.

N 3.3.65 Segregation. A hazard management strategy in which a physical barrier is established between the hazard area and an area to be protected. [654, 2017]

N 3.3.66 Separation. A hazard management strategy achieved by the establishment of a distance as required by the standard between the combustible particulate solid process and other operations that are in the same room. [654, 2017]

N 3.3.67 Spark. A moving particle of solid material that emits radiant energy due to either its temperature or the process of combustion on its surface. [654, 2017]

3.3.68 Spark-Resistant Material. See 3.3.42.3.

3.3.69* Sponge. A porous metal product obtained by processing metal ore prior to being melted.

3.3.70 Spontaneous Heating. Process whereby a material increases in temperature without drawing heat from its surroundings. [921, 2017]

3.3.71 Swarf. Particles produced from a cutting, machining, or grinding operation that causes partial oxidation of the parent material or dilution by other inert materials.

3.3.72 Tantalum Powder. See 3.3.56.5.

3.3.73 Tantalum Ultrafines. (Reserved)

3.3.74* Thermite Reaction. The exothermic reaction between a metal and any metal oxide lower in the electromotive series.

3.3.75 Threshold Dust Accumulation. An established value of dust accumulation, determined as part of the hazard analysis for a particular enclosure of facility and specific metal, for taking an appropriate action.

3.3.76 Titanium Fines. (Reserved)

N 3.3.77 Wall.

N 3.3.77.1 Fire Barrier Wall. A wall, other than a fire wall, having a fire resistance rating. [221, 2018]

N 3.3.77.2 Fire Wall. A wall separating buildings or subdividing a building to prevent the spread of fire and having a fire resistance rating and structural stability. [221, 2018]

3.3.78 Zirconium Fines. (Reserved)

Chapter 4 General

N 4.1 Retroactivity. Sections 4.3 through 4.6 shall apply retroactively.

N 4.2 Owner's Obligation. The facility owner/operator shall be responsible for ensuring that the facility and the systems handling combustible particulate solids are designed, installed, and maintained in accordance with the requirements of this standard and NFPA 652.

N 4.3 Objectives.

N 4.3.1 The design of the facility, processes, and equipment shall be intended to meet the following objectives:

- (1) Life safety
- (2) Structural integrity
- (3) Mission continuity
- (4) Mitigation of fire spread, explosions, or consequential releases of hazardous materials

N 4.3.1.1 The objectives stated in 4.3.1 shall be interpreted as intended outcomes of this standard and not as prescriptive requirements.

N 4.3.1.2 The objectives stated in Section 4.3 shall be deemed to be met when, consistent with 4.3.1 and the provisions in Sections 1.4 and 1.5, both of the following are met:

- (1) The facility, processes, and equipment are designed, constructed, and maintained in accordance with the prescriptive criteria set forth in this standard.
- (2) The management systems set forth in this standard are implemented.

N 4.3.1.3 Where a performance-based alternative design is used, it shall be documented to meet the same objectives as the prescriptive design it replaces in accordance with Chapter 6.

N 4.3.2* Life Safety. The life safety objective shall be deemed to have been met when, consistent with 4.3.1, the provisions in Sections 1.4 and 1.5 and the following are met:

- (1) The facility, combustible particulate processes, and human element programs are designed, constructed, equipped, and maintained to protect personnel not in the immediate proximity of the ignition from the effects of fire, deflagration, explosion, or the consequential release of hazardous materials for the time needed to evacuate, relocate, or take refuge.
- (2) The structure is located, designed, constructed, and maintained to minimize the propagation of fire, explosion, or the consequential release of hazardous materials to adjacent properties and to avoid injury to the public.

N 4.3.3 Structural Integrity. The structural integrity objective shall be deemed to have been met when, consistent with 4.3.1, the provisions in Sections 1.4 and 1.5 are met, and the facility is designed, constructed, and equipped to maintain its structural integrity in spite of the effects of fire, explosion, or the consequential release of hazardous materials for the time necessary to evacuate, relocate, or defend in place occupants not in the immediate proximity of the ignition.

N 4.3.4* Mission Continuity. The mission continuity objective shall be deemed to have been met when, consistent with 4.3.1, the provisions in Sections 1.4 and 1.5 are met, and the facility, processes, equipment, and human element program are designed, constructed, equipped, and maintained to limit

damage to levels that ensure the ongoing mission, production, or operating capability of the facility to a degree acceptable to the owner/operator.

N 4.3.5* Mitigation of Fire Spread, Explosions, and Consequential Release of Hazardous Materials. The mitigation of fire spread and explosions shall be deemed to have been met when, consistent with 4.3.1, the provisions in Sections 1.4 and 1.5 and the following are met:

- (1)* The facility and processes are designed to prevent fires, explosions, or consequential releases of hazardous materials that can cause failure of adjacent compartments, emergency life safety systems, adjacent properties, adjacent storage, or the facility's structural elements.
- (2)* The structure is designed, constructed, and maintained to prevent fire or explosions from causing failure of load-bearing structural members, propagating into adjacent interior compartments, and/or incapacitating fire-protective and emergency life safety systems in adjacent compartments.
- (3) The structure is located, designed, constructed, equipped, and maintained to prevent the propagation of fire or explosion to or from adjacent storage or structures.

N 4.3.6 Where a dust fire, deflagration, or explosion hazard exists within a process system, the hazards shall be managed in accordance with this standard.

N 4.3.7 Where a dust fire, deflagration, or explosion hazard exists within a facility compartment, the effects of the fire, deflagration, or explosion shall be managed in accordance with this standard.

N 4.3.8* Compliance Options. The objectives in 4.3.1 shall be achieved by either of the following means:

- (1) A prescriptive approach in accordance with Chapter 5 and Chapters 7 through 17, as applicable
- (2) A performance-based approach in accordance with Chapter 6

4.4* Management of Change.

4.4.1 Written procedures shall be established and implemented to manage proposed changes to process materials, technology, equipment, procedures, and facilities.

4.4.2 The procedures shall ensure that the following are addressed prior to any change:

- (1) The technical basis for the proposed change
- (2) Safety and health implications, including hazard analysis
- (3) Whether the change is permanent or temporary
- (4) Modifications to operating and maintenance procedures
- (5) Employee training requirements
- (6) Authorization requirements for the proposed change
- (7) Results of characterization tests used to assess the hazard, if conducted

4.4.3 Implementation of the management of change procedure shall not be required for replacements-in-kind.

4.4.4 Design documentation shall be updated to incorporate the change.

4.5 Hazard Analysis.

4.5.1* The design of the fire and explosion safety provisions shall be based on a hazard analysis of the facility, the process, and the associated fire, explosion, and reactivity hazards.

4.5.2 The results of the hazard analysis shall be documented and maintained for the life of the process.

4.5.3 The hazard analysis shall be reviewed and updated at least every 5 years.

4.5.4 New and/or altered operations, equipment, and/or facilities shall be reviewed prior to operation for potential hazards.

4.5.5 Written records shall be maintained of all hazard analyses conducted.

4.5.6 Hazard analyses shall be signed off, prior to operation, by a cognizant authority at the facility.

4.5.7 Appropriate safeguards shall be put in place with regard to findings of the hazard analysis.

4.5.8 Corrective actions as a result of the hazard analysis shall be tracked and completed to ensure that all identified hazards have been abated or that the level of risk has been reduced to a tolerable level by a knowledgeable authority.

4.6* Personal Protective Equipment (PPE).

4.6.1 PPE Hazard Analysis.

4.6.1.1 Requirements for PPE shall be based on a documented analysis of the potential for facility personnel to be exposed to hazards from combustible and molten metals during facility operations and maintenance activities.

4.6.1.2* The PPE hazard analysis shall determine which operations and activities warrant use of primary PPE for molten metals, primary PPE for dust flash fires, and secondary PPE for general work and maintenance in facilities with combustible metals.

4.6.2 Primary PPE for Molten Metals.

4.6.2.1 Primary PPE for molten metals shall include all of the items described in paragraphs 4.6.2.2 to 4.6.2.5.

4.6.2.2 Face shields, neck protection, and safety glasses shall be used as part of the primary PPE for molten metal exposures.

4.6.2.3* External clothing, including but not limited to shirts, trousers, and coveralls, shall meet the performance requirements for primary protective clothing in ASTM F1002, *Standard Performance Specification for Protective Clothing and Materials for Use by Workers Exposed to Specific Molten Substances and Related Thermal Hazards*.

4.6.2.4 Gloves or mittens shall be worn and shall be loose fitting, easily removable, and compatible with the hazards of the pertinent molten metals.

4.6.2.5 Protective footwear shall be high-top leather safety shoes, at least 150 mm (6 in.) high, and appropriate for the hazards of molten metals used in the areas where personnel are working.

4.6.3 Primary PPE for Dust Flash Fires.

▲ 4.6.3.1* Primary PPE for dust flash fires shall include flame-resistant garments in accordance with the workplace hazard assessment required by NFPA 2113.

4.6.3.2* Personnel wearing PPE for dust flash fires shall be informed about the limited protection provided by NFPA 2112-compliant garments against the higher-temperature flames and heat fluxes associated with combustible metal dust flash fires.

4.6.3.3 Primary PPE for dust flash fires shall be designed to prevent potential accumulations of combustible metal dust in places such as, but not limited to, pant cuffs, sleeve cuffs, and open pockets, and shall have a smooth outer surface that allows dust to be readily brushed off.

4.6.3.4 Primary PPE for dust flash fires shall include shirts, trousers, or coveralls.

4.6.3.4.1 Trousers or coveralls shall cover the tops of footwear.

4.6.3.5 Primary PPE for dust flash fires shall include safety shoes without exposed metal.

4.6.3.6* Primary PPE for dust flash fires shall include gloves made of heat-resistant fabrics.

4.6.3.7* When worn in areas containing dusts with minimum ignition energies less than 100 mJ, primary PPE for dust flash fires shall be made of static-dissipative materials.

4.6.4 Secondary PPE for General Work Areas Near or Containing Combustible Metals.

4.6.4.1 Safety glasses with side shields and hard hats shall be required as part of the secondary PPE.

4.6.4.2 Outer garments worn as secondary PPE shall be designed to prevent potential accumulations of combustible metal dust by not having exposed pockets or cuffs, and shall have a smooth outer surface that allows dust to be readily brushed off.

4.6.4.3 Secondary PPE shall have some measure of flame resistance determined as part of the PPE hazard analysis.

4.6.4.4* When worn in areas containing dusts with minimum ignition energies less than 100 mJ, secondary PPE shall be made of static-dissipative materials.

4.6.4.5 Secondary PPE worn in areas containing alkali metals shall have an external clothing layer that is impervious to body moisture.

▲ 4.6.4.5.1* Proper protective clothing, respiratory protection, and adequate eye protection shall be used by all responding fire-fighting personnel assigned to a combustible metal fire equipped to the requirements of NFPA 600 or NFPA 1081.

4.7 Dust Explosion and Flash-Fire Hazard Areas.

4.7.1 Those portions of the process and facility where deflagration venting is not currently required and a dust explosion hazard or flash-fire hazard exists shall be evaluated to determine appropriate protection levels from the effects of these hazards in accordance with this section and the fire protection and building construction sections in each metal chapter — Chapter 14 through 16 — and Chapter 8.

4.7.2 Dust explosion hazard areas and dust flash-fire hazard areas shall be deemed to exist in all operating areas of facilities processing or handling combustible metal dusts unless a hazard analysis determines otherwise.

4.8 Segregation, Separation, or Detachment to Limit Dust Hazard Areas.

4.8.1 It shall be permitted to use segregation, separation, or detachment to limit the extent of a dust explosion hazard area or a dust flash-fire hazard area.

4.8.2 Use of Segregation.

4.8.2.1 Physical barriers that are erected to segregate dust flash-fire hazard areas, including seals at all penetrations of floors, walls, ceilings, or partitions shall have a 1-hour fire resistance rating.

▲ 4.8.2.2 Physical barriers that are erected to segregate dust explosion hazard areas shall be designed to preclude failure of those barriers during a dust explosion in accordance with NFPA 68.

4.8.2.3 Doors and openings shall not be permitted in physical barriers unless they are normally closed and have at least the strength and fire resistance rating required of the physical barrier.

4.8.3 Use of Separation.

4.8.3.1* Where separation is used to limit the dust flash-fire hazard area, the required separation distance between the flash-fire hazard area and surrounding exposures shall be determined by the following:

- (1) Engineering evaluation that addresses the properties of the materials
- (2) Type of operation
- (3) Amount of material likely to be present outside the process equipment
- (4) Building design
- (5) Nature of surrounding exposures

4.8.3.2 Where separation is used to limit the dust flash-fire hazard area, in no case shall the required separation distance determined in 4.8.3.1 be less than 11 m (35 ft).

4.8.3.3 Where separation is used, housekeeping fixed-dust collection systems employed at points of release, and compartmentation shall be permitted to be used to limit the extent of the dust flash-fire hazard area.

4.8.3.4* Where separation is used to limit a dust flash-fire hazard area, the hazard analysis shall be applied to this limited area.

4.8.3.5 Where a limited area is both a dust flash-fire hazard area and a dust explosion hazard area, separation shall not be permitted to be used to reduce the dust flash-fire hazard area.

▲ 4.9* Organometallic Materials. (Reserved)

Chapter 5 Determination of the Combustibility or Explosibility of a Metal, Metal Powder, or Metal Dust

5.1* Overview. The screening test in Section 5.3 and in Section 5.4 shall be conducted to determine if a metal is in combustible or explosible form.

5.1.1 If either of the tests produces a positive result, the material shall be considered a combustible metal.

5.1.2 Test results shall be documented, the AHJ shall be notified, and the test results shall be provided when requested.

5.1.3 Documentation of noncombustibility proven through analytical testing of combustibility and explosibility of the specific forms of these materials, as described in this chapter and acceptable to the AHJ, is required to eliminate application of this standard.

5.1.4 Application of This Document.

5.1.4.1 Only those specific forms of combustible metals, powders, dusts, and alloys of those materials that can be documented through accepted testing, and shown in that form not to satisfy the conditions and definitions of combustibility and explosibility, shall qualify for exclusion from the requirements of this document. (See 1.1.6 for additional information.)

5.1.4.2 Wherever combustibility can be shown to exist in these materials, the full scope and requirements of this document shall apply.

5.1.4.3 Wherever the documentation necessary for compliance with 5.1.2 and 5.1.3 is lacking, the requirements of this document shall apply.

5.1.5* Test samples for the preliminary screening tests shall be tested in forms that reflect actual process conditions. Variations in process and material conditions shall be assessed and documented in the selection of test sample materials.

5.1.5.1 Representative samples shall be collected from the process and preserved in suitable inert gas or vacuum packaging until tested.

5.1.6 Forms of combustible metal dust (CMD) that have been evaluated as noncombustible shall be required to be re-evaluated whenever a change in manufacture, processing, handling, or storage conditions creates a modified form that might exhibit the characteristic of combustibility.

5.2* Basic Material Characterization.

5.2.1* Representative samples and components of metal-containing mixtures shall be collected and identified.

5.2.2* Collected samples, including metal-containing mixtures, shall be subject to basic materials characterization to include at a minimum composition, form, particle size and distribution, and moisture content.

5.3 Determination of Combustibility.

▲ **5.3.1*** Combustibility shall be determined for metals, metal powders, and metal dusts by the preliminary screening test set forth in Part III, Subsection 33.2.1 of the *UN Recommendations on the Transport of Dangerous Goods: Model Regulations — Manual of Tests and Criteria*.

5.3.1.1 Representative samples shall be maintained in suitable inert gas or vacuum packaging until tested.

5.3.2 For purposes of determining the combustibility of metal powders, pastes, finely divided materials, and metal dusts, the results of the screening test shall be categorized as one of the following three categories:

- (1) No reaction
- (2) Glowing but no propagation along the powder train
- (3) Propagation along the powder train past the heated zone

5.3.3 If the results of the screening test provide either no reaction or glowing but no propagation along the powder train past the heated zone by burning with flame or smoldering, the test material shall be considered to be in a noncombustible form.

5.3.4* If the material, in the form tested, ignites and propagates combustion, or ejects sparks from the heated zone after the heat source is removed, or ignites before the ignition source is applied to the sample, the material shall be considered combustible and the standard shall be applicable.

5.3.5* For materials other than dusts, powders, pastes, or other finely divided material, the flame from a 1000°C (1832°F) torch shall be applied for 10 minutes.

5.3.5.1* If the material does not sustain combustion, it shall be considered to be a metal in a noncombustible form.

5.3.5.2 Safety measures shall be taken based on the assumption that the test will result in combustion.

5.4 Determination of Explosibility.

5.4.1* The explosibility of metals, metal powders, metal dusts, and alloys of these materials shall be determined by using the flow chart in Figure 5.4.1.

5.4.1.1* If the material is determined to be explosible, some or all of the standard test methods in Figure 5.4.1 shall be performed as needed by the hazard analysis as described in Section 4.5. If a sample either ignites during ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, screening testing prior to ignition source energizing, or results in a positive classification, it shall be considered to be explosible.

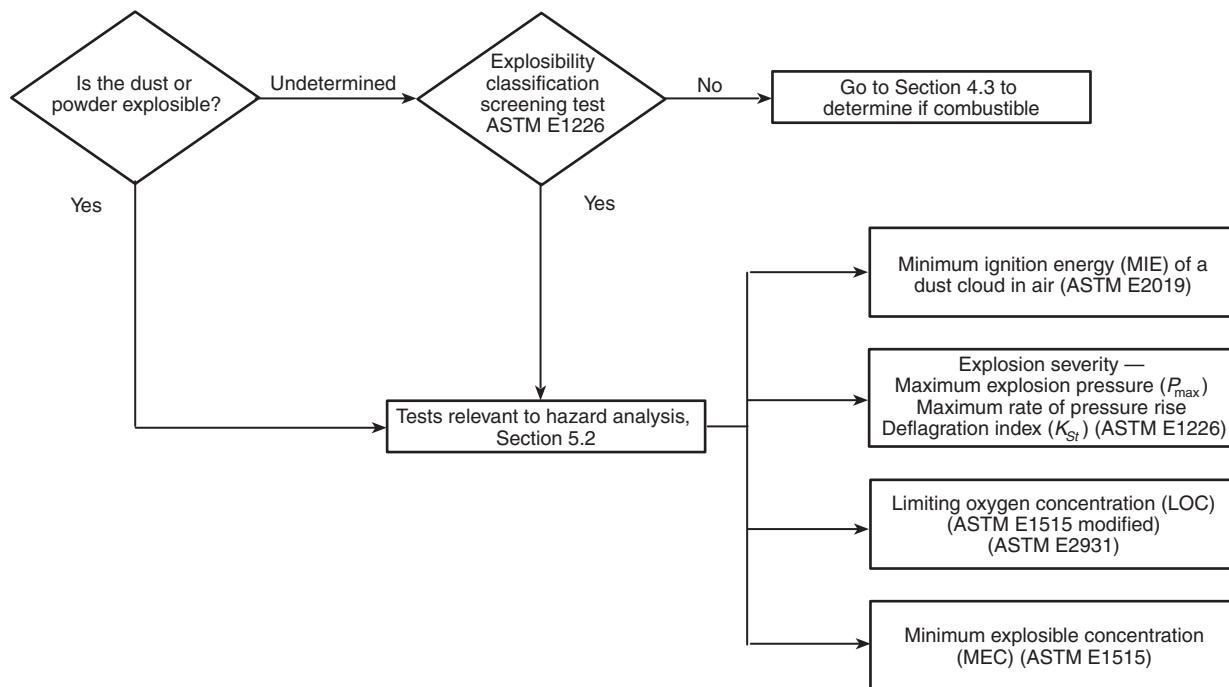
5.4.1.2 Additional tests chosen shall be those relevant to hazard analysis of the intended explosion protection techniques and flash-fire hazards anticipated for the process.

5.4.2* The explosibility classification screening test shall serve as the basis to determine whether a metal, metal powder, metal dust, or alloy of these materials is capable of initiating or sustaining an explosion when suspended as a dust cloud.

5.4.3* Test samples for the explosibility classification screening tests shall be tested in forms that reflect actual process conditions and the normal composition of the material with respect to particle size distribution, moisture content, and chemical composition. Variations in process and material conditions shall be assessed and documented in the selection of test sample materials.

5.4.3.1 Representative samples shall be maintained in suitable inert gas or vacuum packaging until tested.

5.4.4* The explosibility classification screening tests shall be conducted in accordance with ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*.



▲ FIGURE 5.4.1 Determination of Explosibility.

5.5 Use of Test Data for Hazard Analysis.

5.5.1* The hazard analysis shall be based on data from tests of collected samples or historical data.

5.5.2* If historical data are used, an assessment of the composition, form, and particle size distribution, at a minimum, shall be compared to ensure the historical data are representative of the current material.

5.6* Determination of Flash Fire Potential. (Reserved)

▲ **5.7 Risk Evaluation.** Where a risk evaluation (*see Annex I*) is required by the AHJ, material property data and material handling and processing conditions shall be reviewed to determine the likelihood and consequences of a metal powder or dust ignition. It shall be permitted to make qualitative determinations of likelihood and consequences, providing at least some of the following property data are included in the determinations:

- (1) Minimum ignition energy (MIE)
- (2) Maximum pressure (P_{\max})
- (3) Maximum rate of pressure rise (dP/dt_{\max})
- (4) Deflagration index (K_{St})
- (5) Limiting oxygen concentration (LOC)
- (6) Minimum explosible concentration (MEC)
- (7) Thermal stability
- (8) Electrostatic risk
- (9) Reactivity

▲ **5.8 Compliance Options.** If the material has been determined to be either explosible or combustible by this chapter, compliance shall be achieved by either of the following methods:

- (1) The prescriptive provisions in accordance with Chapter 5 and Chapters 7 through 17
- (2) The performance-based provisions in accordance with Chapter 6

Chapter 6 Performance-Based Design Option

6.1 General Requirements.

6.1.1 Approved Qualifications. The performance-based design shall be prepared by a person with qualifications acceptable to the owner/operator.

6.1.2 Independent Review. The authority having jurisdiction shall be permitted to obtain an independent third-party review of the proposed design.

▲ **6.1.3*** Performance-based designs shall be documented with all calculations, references, assumptions, and sources from which material characteristics and other data have been obtained or on which the designer has relied for some material aspect of the design in accordance with Chapter 5 of NFPA 101.

6.1.3.1 A sensitivity analysis shall be performed for each assumption that is not provided in an authoritative reference acceptable to the authority having jurisdiction to show that variation of said assumption does not result in a failure to meet design criteria.

6.1.3.2 The source of all calculation methods and models shall be documented with their limits of applicability.

6.1.4* Performance-based designs and documentation shall be updated and subject to re-approval if any of the assumptions on which the original design was based are changed.

6.1.5 Sources of Data.

6.1.5.1 Data sources shall be identified and documented for each input data requirement that must be met using a source other than a design fire scenario, an assumption, or a building design specification.

6.1.5.2 The degree of conservatism reflected in such data shall be specified, and a justification for the sources shall be provided.

6.2 Design Objectives.

6.2.1 Life Safety.

6.2.1.1 The facility, combustible particulate processes, and human element programs shall be designed, constructed, equipped, and maintained to protect personnel not in the immediate proximity of the ignition from the effects of fire, deflagration, explosion, or the **consequential** release of hazardous materials for the time needed to evacuate, relocate, or take refuge.

6.2.1.2 The structure shall be located, designed, constructed, and maintained to minimize the propagation of fire, explosion, or the **consequential** release of hazardous materials to adjacent properties and to avoid injury to the public.

6.2.2 Structural Integrity. The facility shall be designed, constructed, and equipped to maintain its structural integrity in spite of the effects of fire, explosion, or the **consequential** release of hazardous materials for the time necessary to evacuate, relocate, or defend in place occupants not in the immediate proximity of the ignition.

6.2.3* Mission Continuity. The facility, processes and equipment, and human element program shall be designed, constructed, equipped, and maintained to limit damage to levels that ensure the ongoing mission, production, or operating capability of the facility to a degree acceptable to the owner/operator.

6.2.4 Mitigation of Fire Spread, Explosions, or Releases of Hazardous Materials. The facility and processes shall be designed to prevent fires, explosions, or releases of hazardous materials that can cause failure of adjacent compartments, emergency life safety systems, adjacent properties, adjacent storage, or the facility's structural elements.

6.2.4.1* The structure shall be designed, constructed, and maintained to prevent fire or explosions from causing failure of load-bearing structural members, propagating into adjacent interior compartments, and incapacitating fire-protective and emergency life safety systems in adjacent compartments.

6.2.4.2 The structure shall be located, designed, constructed, equipped, and maintained to prevent the propagation of fire or explosion to or from adjacent storage or structures.

6.3 Performance Criteria. A system and facility design shall be deemed to meet the objectives specified in Section 6.2 if its performance meets the criteria in 6.3.1 through 6.3.5.

6.3.1 Life Safety.

6.3.1.1 The life safety objectives of 6.2.1 with respect to a fire hazard shall be achieved if either of the following criteria is met:

- (1) Ignition has been prevented.
- (2) Under all fire scenarios, no person, other than those in the immediate proximity of the ignition, is exposed to untenable conditions due to the fire, and no critical structural element of the building is damaged to the extent that it can no longer support its design load during the period of time necessary to effect complete evacuation.

6.3.1.2 The life safety objectives of 6.2.1 with respect to an explosion hazard shall be achieved if either of the following criteria is met:

- (1) Ignition has been prevented.
- (2) Under all explosion scenarios, no person, other than those in the immediate proximity of the ignition, is exposed to untenable conditions, including missile impact or overpressure, due to the occurrence of an explosion, and no critical structural element of the building is damaged to the extent that it can no longer support its design load during the period of time necessary to effect complete evacuation.

6.3.1.3 The life safety objectives of 6.2.1 with respect to the **consequential** release of hazardous materials that don't result in a fire or explosion shall be achieved if the following criteria are met:

- (1) The physical and health hazards identified are mitigated.
- (2) Releases of all hazardous materials offsite are minimized.

6.3.2 Structural Integrity. The structural integrity objective of 6.2.2 with respect to fire and explosion shall be achieved when no critical structural element of the building is damaged to the extent that it can no longer support its design load under all fire and explosion scenarios.

6.3.3 Mission Continuity. The mission continuity objectives of 6.2.3 shall be achieved when damage to equipment and the facility has been limited to a level of damage acceptable to the owner/operator.

6.3.4 Mitigation of Fire Spread, Explosions, or the Consequential Release of Hazardous Materials. When limitation of fire spread is to be achieved, all of the following criteria shall be demonstrated:

- (1) Adjacent combustibles shall not attain their ignition temperature.
- (2) Building design and housekeeping shall prevent combustibles from accumulating exterior to the enclosed process system to a concentration that is capable of supporting propagation.
- (3) Particulate processing systems shall prevent fire or explosion from propagating from one process system to an adjacent process system or to the building interior.

6.3.5 Effects of Explosions. Where the prevention of damage due to explosion is to be achieved, deflagrations shall not produce any of the following conditions:

- (1) Internal pressures in the room or equipment sufficient to threaten its structural integrity
- (2) Extension of the flame front outside the compartment or equipment of origin except where intentionally vented to a safe location
- (3)* Rupture of the compartment or equipment of origin and the ejection of fragments that can constitute missile hazards

6.4* Design Scenarios.

6.4.1 Fire Scenarios.

6.4.1.1* Each fuel object in the compartment shall be considered for inclusion as a fire scenario.

6.4.1.2 The fuel object that produces the most rapidly developing fire during startup, normal operating conditions, or shutdown shall be included as a fire scenario.

6.4.1.3 The fuel object that produces the most rapidly developing fire under conditions of a production upset or single equipment failure shall be included as a fire scenario.

6.4.1.4 The fuel object that produces the greatest total heat release during startup, normal operating conditions, or shutdown shall be included as a fire scenario.

6.4.1.5 The fuel object that produces the greatest total heat release under conditions of a production upset or single equipment failure shall be included as a fire scenario.

6.4.1.6 The fuel object that can produce a deep-seated fire during startup, normal operating conditions, or shutdown shall be included as a fire scenario.

6.4.1.7 The fuel object that can produce a deep-seated fire under conditions of a production upset or single equipment failure shall be included as a fire scenario.

6.4.2 Explosion Scenarios.

6.4.2.1 Each duct, enclosed conveyor, silo, bunker, cyclone, dust collector, or other vessel containing a combustible metal dust in sufficient quantity or conditions to support the propagation of a flame front during startup, normal operating conditions, or shutdown shall be included as an explosion scenario.

6.4.2.2 Each duct, enclosed conveyor, silo, bunker, cyclone, dust collector, or other vessel containing a combustible metal dust in sufficient quantity or conditions to support the propagation of a flame front under conditions of production upset or single equipment failure shall be included as an explosion scenario.

6.4.2.3 Each building or building compartment containing a combustible metal dust in sufficient quantity or conditions to support the propagation of a flame front during startup, normal operating conditions, or shutdown shall be included as an explosion scenario.

6.4.2.4 Each building or building compartment containing a combustible metal dust in sufficient quantity or conditions to support the propagation of a flame front under conditions of production upset or single equipment failure shall be included as an explosion scenario.

6.4.2.5 Other Explosions Such as Hydrogen, Steam, Chemical, or Hazardous Materials Reactions. (Reserved)

6.5 Evaluation of Proposed Design.

6.5.1* General. A proposed design's performance shall be assessed relative to each performance objective in Section 6.2 and each applicable scenario in Section 6.4, with the assessment conducted through the use of appropriate calculation methods acceptable to the authority having jurisdiction.

6.5.2 The design professional shall establish numerical performance criteria for each of the objectives in Section 6.2.

6.5.3 The design professional shall use the assessment methods to demonstrate that the proposed design will achieve the goals and objectives, as measured by the performance criteria in light of the safety margins and uncertainty analysis, for each scenario, given the assumptions.

Δ 6.6 Retained Prescriptive Requirements. Portions of a facility designed in accordance with this chapter as an alternative for particular prescriptive requirements shall meet all other relevant prescriptive requirements in this standard.

N Chapter 7 Hazard Analysis

N 7.1* General.

N 7.1.1* Retroactivity. The requirements of Chapter 7 shall apply retroactively.

N 7.1.2 Solid metal in a combustible form shall meet the requirements of Section 5.2.

N 7.1.3 Combustible metal dusts shall meet the requirements of Section 7.2.

N 7.1.4 Molten combustible metals shall meet the requirements of Section 7.3.

N 7.1.5 The design of the fire and explosion safety provisions shall be based on a hazard analysis of the facility, the process, and the associated fire and explosion hazards.

N 7.2 Dust Hazard Analysis (DHA).

N 7.2.1 Responsibility. The owner/operator of a facility where materials that have been determined to be combustible or explosible in accordance with Chapter 5 are present in an enclosure shall be responsible to ensure a DHA is completed in accordance with the requirements of this chapter. [652:7.1.1]

N 7.2.1.1 For existing processes and facility compartments that are undergoing modification, the owner/operator shall complete a DHA.

N 7.2.1.2 New or altered operations, equipment, or facilities shall be reviewed for potential hazards prior to operation.

N 7.2.1.3* The design of the fire and explosion safety provisions shall be based on a hazard analysis of the facility, the process, and the associated fire and explosion hazards.

N 7.2.1.4 The DHA shall be reviewed and updated at least every five years.

N 7.2.2 Criteria.

N 7.2.2.1* Overview. The DHA shall evaluate the fire, deflagration, reactivity, and explosion hazards and provide recommendations to manage the hazards in accordance with Section 4.3. [652:7.2.1]

N 7.2.2.2* Qualifications. The DHA shall be performed or led by a qualified person. [652:7.2.2]

N 7.2.2.2.1 The DHA shall be signed off, prior to operation, by a cognizant authority at the facility.

N 7.2.2.3 Documentation. The results of the DHA review shall be documented, including any necessary action items requiring change to the process materials, physical process, process operations, or facilities associated with the process. [652:7.2.3]

N 7.2.2.3.1 The results of the hazard analysis shall be maintained for the life of the process.

N 7.2.3 Methodology.

N 7.2.3.1 General. The DHA shall include the following:

- (1) Identification and evaluation of the process or facility areas where fire, flash fire, and explosion hazards exist

(2) Where such a hazard exists, identification and evaluation of specific fire and deflagration scenarios shall include the following:

- (a) Identification of safe operating ranges
- (b)* Identification of the safeguards that are in place to manage fire, deflagration, and explosion events
- (c) Recommendation of additional safeguards where warranted, including a plan for implementation

[652:7.3.1]

N 7.2.3.1.1 Recommendations from the DHA shall be tracked to completion.

N 7.2.3.2 Material Evaluation. The DHA shall be based on data obtained in accordance with Chapter 5 for material that is representative of the dust present.

N 7.2.3.3 Process Systems.

N 7.2.3.3.1* Each part of the process system where combustible metal dust is present, or where combustible metal particulate solids could cause combustible metal dust to be present, shall be evaluated, and the evaluation shall address the following:

- (1) Potential intended and unintended combustible metal dust transport between parts of the process system
- (2) Potential fugitive combustible metal dust emissions into a building or building compartments, including powder and fugitive material as defined by this document
- (3) Potential deflagration propagation between parts of the process system
- (4) Reactivity of the combustible metal

N 7.2.3.3.2 Each part of the process that contains a combustible metal particulate solid and that can potentially include both of the following conditions shall be considered a fire hazard and shall be documented as such:

- (1) Oxidizing atmosphere
- (2) Credible ignition source

N 7.2.3.3.3* Each part of the process that contains a sufficient quantity of combustible metal dust to propagate a deflagration and that can potentially include all the following conditions shall be considered a dust deflagration hazard and shall be documented as such:

- (1) Oxidizing atmosphere
- (2) Credible ignition source
- (3) Credible suspension mechanism

N 7.2.3.4 Building or Building Compartments.

N 7.2.3.4.1 Each building or building compartment where combustible metal dust is present shall be evaluated.

N 7.2.3.4.1.1 Where multiple buildings or building compartments present essentially the same hazard, a single evaluation shall be permitted to be conducted as representative of all similar buildings or building compartments. [652:7.3.4.1.1]

N 7.2.3.4.1.2 The evaluation shall address potential combustible metal dust migration between buildings or building compartments.

N 7.2.3.4.1.3 The evaluation shall address potential deflagration propagation between buildings or building compartments. [652:7.3.4.1.3]

N 7.2.3.4.2* Each building or building compartment that contains a combustible metal particulate solid and that can

potentially include both of the following conditions shall be considered a fire hazard and shall be documented as such:

- (1) Oxidizing atmosphere
- (2) Credible ignition source

N 7.2.3.4.2.1 The evaluation of dust deflagration hazard in a building or building compartment shall include a comparison of actual or intended dust accumulation to the threshold housekeeping dust accumulation that would present a potential for flash-fire exposure to personnel or compartment failure due to explosive overpressure. [652:7.3.4.2.1]

N 7.2.3.4.2.2 Threshold housekeeping dust accumulation levels and nonroutine dust accumulation levels (e.g., from a process upset) shall be in accordance with this standard.

N 7.2.3.4.3 Each building or building compartment that contains a sufficient quantity of combustible metal dust to propagate a deflagration and that can potentially include all of the following conditions shall be considered a dust deflagration hazard and shall be documented as such:

- (1) Oxidizing atmosphere
 - (2) Credible ignition source
 - (3) Credible suspension mechanism
- [652:7.3.4.3]

N 7.3 Molten Metal Hazard Analysis.

N 7.3.1 Responsibility. The owner/operator of a facility where combustible metals are present in a molten state shall be responsible to ensure a hazard analysis is completed in accordance with the requirements of this section.

N 7.3.1.1 For existing processes and facility compartments that are undergoing modification, the owner/operator shall complete a hazard analysis.

N 7.3.1.2 New or altered operations, equipment, or facilities shall be reviewed prior to operation for potential hazards.

N 7.3.1.3 The hazard analysis shall be reviewed and updated at least every five years.

N 7.3.2 Criteria.

N 7.3.2.1 Overview. The hazard analysis shall evaluate the fire, reactivity, and explosion hazards and provide recommendations to manage the hazards in accordance with Section 4.3.

N 7.3.2.1.1 Reactivity hazards shall include potential molten metal/water interactions.

N 7.3.2.2* Qualifications. The hazard analysis shall be performed or led by a qualified person.

N 7.3.2.2.1 Hazard analyses shall be signed off, prior to operation, by a cognizant authority at the facility.

N 7.3.2.3 Documentation. The results of the hazard analysis review shall be documented, including any necessary action items requiring change to the process materials, physical process, process operations, or facilities associated with the process.

N 7.3.2.3.1 The results of the hazard analysis shall be maintained for the life of the process.

N 7.3.3 Methodology.

N 7.3.3.1 General. The hazard analysis shall include the following:

- (1) Identification and evaluation of the process or facility areas where fire, reactivity, and explosion hazards exist
- (2) Where such a hazard exists, identification and evaluation of specific fire, reactivity, and deflagration scenarios shall include the following:
 - (a) Identification of safe operating ranges
 - (b)* Identification of the safeguards that are in place to manage fire, reactivity, deflagration, and explosion events
 - (c) Recommendation of additional safeguards where warranted, including a plan for implementation

N 7.3.3.1.1 Recommendations from the hazard analysis shall be tracked to completion.

N 7.3.3.1.2 Hazard analyses shall be signed off, prior to operation, by a cognizant authority at the facility.

N 7.3.3.2 Material Evaluation.

N 7.3.3.2.1 The hazard analysis shall be based on data that is representative of the molten metal present.

N 7.3.3.3 Process Systems.

N 7.3.3.3.1* Each part of the process system where combustible metal in a molten form is present shall be evaluated, and the evaluation shall address the following:

- (1) Potential intended and unintended runout of combustible molten metal between parts of the process system
- (2) Potential runout of combustible molten metal from the process system into a building or building compartments, including potential interaction with water in the building or building compartments
- (3) Potential explosion impacts on other parts of the process system
- (4) Reactivity of the combustible molten metal

N 7.3.3.3.2 Each part of the process that contains a combustible metal in molten form and that can potentially include both of the following conditions shall be considered a fire hazard and shall be documented as such:

- (1) Oxidizing atmosphere
- (2) Combustible loading in the melting area

N 7.3.3.3.3* Each part of the process that contains a sufficient quantity of combustible molten metal to propagate a fire or explosion and that can potentially include all the following conditions shall be considered a fire or explosion hazard and shall be documented as such:

- (1) Oxidizing atmosphere
- (2) Combustible loading in the melting area
- (3) Water or other reactive materials in the melting area

N 7.3.3.4 Building or Building Compartments.

N 7.3.3.4.1 Each building or building compartment where combustible metal in a molten form is present shall be evaluated.

N 7.3.3.4.1.1 Where multiple buildings or building compartments present essentially the same hazard, a single evaluation

shall be permitted to be conducted as representative of all similar buildings or building compartments. [652:7.3.4.1.1]

N 7.3.3.4.1.2 The evaluation shall address potential combustible molten metal flow between buildings or building compartments.

N 7.3.3.4.1.3 The evaluation shall address potential fire or explosion propagation between buildings or building compartments. [652:7.3.4.1.3]

N 7.3.3.4.2 Each building or building compartment that contains a combustible molten metal and that can potentially include both of the following conditions shall be considered a fire hazard and shall be documented as such:

- (1) Oxidizing atmosphere
- (2) Combustible loading in the melting area
- (3) Water or other reactive materials in the melting area

Chapter 8 Fire Prevention, Fire Protection, and Emergency Response

N 8.1 Retroactivity. The requirements of this chapter shall apply retroactively.

8.2 Fire Prevention.**8.2.1 Inspection and Maintenance.**

8.2.1.1 An inspection, testing, and maintenance program shall be implemented that ensures that process controls and equipment perform as designed and that a change in process equipment does not increase the hazard.

8.2.1.2 The inspection, testing, and maintenance program shall include the following:

- (1) Fire and explosion protection and prevention equipment in accordance with the applicable NFPA codes and standards
- (2) Dust control equipment
- (3) Housekeeping
- (4) Potential ignition sources
- (5) Electrical, process, and mechanical equipment, including process interlocks
- (6) Process changes
- (7) Continuity check on grounding and bonding systems
- (8) Resistivity testing of static-dissipative footwear and conductive floors where required
- (9) Piping systems that carry or transport combustible/flammable gases, liquids, and/or hazardous chemicals, or materials that can interact and present a hazard should a release occur, (i.e., water lines in the vicinity of molten metal).

8.2.1.3 A thorough inspection of the operating area shall take place on an as-needed basis to help ensure that the equipment is in good condition and that proper work practices are being followed.

8.2.1.3.1 The inspection shall be conducted at least quarterly.

8.2.1.3.2 The inspection shall be conducted by a person(s) knowledgeable in the proper practices who shall record the findings and recommendations.

8.2.1.4 Operating and maintenance procedures shall be reviewed annually and as required by process changes.

8.2.2 Control of Combustible Materials.

- △ 8.2.2.1 Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30.

8.2.2.1.1 Forge presses, heavy grinders, and other milling equipment operated by hydraulic systems of 189 L (50 gal) or greater shall use a less hazardous hydraulic fluid with a flash point greater than 93°C (200°F).

- △ 8.2.2.1.2 Dipping and coating applications of flammable or combustible liquids shall be done in accordance with NFPA 34.

- △ 8.2.2.1.3 Spray application of flammable or combustible liquids shall be done in accordance with NFPA 33.

8.2.2.2 Ordinary Combustible Storage.

8.2.2.2.1 Ordinary combustible materials, such as paper, wood, cartons, and packing material, shall not be stored or allowed to accumulate in processing areas unless necessary for the process, and then only in designated areas.

8.2.2.2.2 Ordinary combustible materials shall not be discarded in containers used for the collection of combustible metal waste.

8.2.2.3 Removal of Combustible Metal Chips, Fines, Swarf, Paste, Powder, Dust, and Sweepings.

8.2.2.3.1 All combustible metal chips, lathe turnings, and swarf shall be collected in closed-top metal containers and removed daily, as a minimum, to a safe storage or disposal area.

8.2.2.3.2 Open storage of sponge, chips, fines, and dust that are readily ignitable shall be isolated and segregated from other combustible materials and metal scrap to prevent propagation of a fire.

8.2.3* Molten Metal.

8.2.3.1 All containers used to receive molten metal, molten titanium, molten titanium chloride, or liquid alkali metals shall be cleaned and dried thoroughly before use.

8.2.3.2 All pieces of metal shall be clean and dry when charged to reactors.

8.3 Fire Protection.

8.3.1 Automatic Sprinkler Protection for Combustible Metals Other Than Alkali Metals.

8.3.1.1* Automatic sprinkler protection shall not be permitted in areas where combustible metals are produced or handled unless allowed by 8.3.1.2, 8.3.1.3, and 8.3.1.4.

- △ 8.3.1.2* Sprinkler systems installed in accordance with NFPA 13 shall be permitted in areas where combustibles other than combustible metals in molten form or in a state that could cause an immediate explosive reaction with water create a more severe hazard, as determined by a hazards analysis, than the metals and where acceptable to an authority having jurisdiction knowledgeable of the hazards associated with combustible metals.

8.3.1.3 The hazards analysis shall consider the possibility of fires and explosions involving both combustible metals and the other combustibles.

8.3.1.4 The special hazards associated with metals in a combustible form and in contact with water shall be considered

in the selection, design, and installation of automatic sprinkler systems.

8.3.1.5 Employee training and organizational planning shall be provided to ensure safe evacuation of the areas that contain combustible metal hazards in case of fire in accordance with 8.3.4.

8.3.1.6* Light casting storage areas shall be protected by automatic sprinklers in any of the following situations:

- (1) Where storage in quantities greater than 28 m³ (989 ft³) is contained in a building of combustible construction
- (2) Where magnesium products are packed in combustible crates or cartons
- (3) Where other combustible storage is within 9 m (30 ft) of the magnesium

8.3.2 Sprinkler Protection for Alkali Metals.

8.3.2.1* Buildings or portions of buildings in which the only combustible hazard present is alkali metals shall not be permitted to be equipped with sprinkler protection.

8.3.2.2 Buildings or portions of buildings that have combustible hazards in addition to alkali metals shall be evaluated for fire protection requirements with a hazards analysis that is acceptable to the authority having jurisdiction.

- △ 8.3.2.3 Sprinkler systems installed in accordance with NFPA 13 shall be permitted in areas where combustibles other than alkali metals create a more severe fire hazard than the alkali metals and where acceptable to an authority having jurisdiction knowledgeable of the hazards associated with alkali metals.

8.3.2.4 As an alternative, a specially engineered fire protection system specifically designed to be compatible with the hazards present in the alkali metals operation area shall be permitted to be installed in areas where combustible loading is essential to the process operation.

8.3.2.5 Fire-extinguishing agents compatible for the hazards present shall be readily available in combustible metals-scraps storage areas.

8.3.2.6* Fire-extinguishing agents compatible for the hazards present shall be readily available in combustible-metals-powder storage areas.

8.3.3* Extinguishing Agents and Application Techniques.

8.3.3.1* Class D extinguishing agents or those agents shown to be effective for controlling combustible-metal fires shall be provided in areas where metals in a combustible form are present.

8.3.3.1.1 The effectiveness of the fire suppressing agent for controlling, suppressing, or extinguishing a fire involving a specific combustible metal shall be demonstrated to the AHJ or supported by third-party testing.

8.3.3.1.2 Any agent that when applied at the recommended rate results in an increase in fire intensity shall be prohibited.

8.3.3.2 A supply of extinguishing agent for manual application shall be kept within easy reach of personnel working with combustible metal powder.

8.3.3.3 Container lids shall be kept in place to prevent agent contamination and to keep agents moisture free.

▲ **8.3.3.4** Portable or wheeled extinguishers listed for use on combustible-metal fires shall be provided and shall be distributed in accordance with NFPA 10.

8.3.3.5 The following agents shall not be used as extinguishing agents on a combustible-metal fires because of adverse reactions or ineffectiveness unless they are compatible with the metal and are an effective extinguishing agent (*see 8.3.3*):

- (1) Water
- (2) Foams
- (3) Halon
- (4) Carbon dioxide
- (5)* Nitrogen (IG-100)
- (6) Halocarbon Clean Agents

8.3.3.6 A:B:C dry-chemical and B:C dry-chemical extinguishers shall not be used as an extinguishing agent on a combustible-metal fire but shall be permitted to be used on other classes of fires in the area where combustible metals are present.

8.3.3.7 Fire-extinguishing agent expellant gases shall be compatible with the combustible metal.

8.3.3.8 Where Class A, Class B, or Class C fire hazards are in the combustible-metal area, extinguishers suitable for use on such fires shall be permitted, provided they are marked "Not for Use on Combustible-Metal Fires."

8.3.3.9* Solvent-Wetted Powders. Incipient fires in solvent-wetted powders shall be handled according to **8.3.3.9.1** or **8.3.3.9.2**.

8.3.3.9.1 An incipient fire occurring while the metal powder is in slurry form shall be permitted to be fought using listed Class B extinguishing agents, except that halogenated extinguishing agents shall not be used.

8.3.3.9.2 An incipient fire occurring in semi-wet material or filter cake shall be fought using a listed Class B extinguishing agent.

8.3.3.9.2.1* Where Class B extinguishing agents are used to extinguish fires involving solvent-wetted aluminum, the residual material shall be immediately covered with dry sand, with dry inert granular material, or with another listed Class D extinguishing agent, and the entire mass shall be allowed to cool until it reaches ambient temperature.

8.3.3.9.2.2* When the material has cooled and it has been determined that there are no hot spots, the covered material shall be carefully removed for disposal.

8.3.3.9.2.3 The material shall be handled in covered containers.

8.3.3.10 Applications of Extinguishing Agents. Applications of extinguishing agents shall be handled according to **8.3.3.10.1** through **8.3.3.10.4**.

8.3.3.10.1* An incipient fire shall be ringed with a dam of dry sand, with dry material that will not react with the metal being extinguished, or with a listed or approved Class D extinguishing powder in accordance with the manufacturer's instructions.

8.3.3.10.2 Application of dry extinguishing agent shall be conducted in such a manner as to avoid any disturbance of the combustible-metal dust, which could cause a dust cloud.

8.3.3.10.3* The use of pressurized extinguishing agents shall not be permitted on a combustible-metal powder fire or chip fire, unless applied carefully so as not to disturb or spread the combustible-metal powder or chip fire.

8.3.3.10.4 Only listed or approved Class D extinguishing agents or those tested and shown to be effective for extinguishing combustible-metal fires shall be permitted in combustible metal processing locations at risk for combustible metal fires.

8.3.3.11 Fire-extinguishing agents compatible for the hazards present shall be available in metal-scrap storage areas.

8.3.3.12 Fire-extinguishing agents compatible for the hazards present shall be available in metal-powder storage areas.

8.3.4 Fire-Fighting Activities.

8.3.4.1* Trained employees shall be permitted to fight incipient-stage fires, provided the fire can be controlled with portable extinguishers or other dry extinguishing agent.

8.3.4.2 In case of fire in the chips, turnings, or powder compact, the pan or tray shall not be disturbed or moved, except by an individual knowledgeable in the fire aspects of combustible metals, until the fire has been extinguished and the material has cooled to ambient temperature.

8.3.4.3 Combustible-metal fires beyond the incipient stage shall be fought by professional fire fighters, specially trained fire brigade personnel, or both.

8.3.4.4 Once the fire is extinguished and a crust is formed, the crust shall not be disturbed until the residue has cooled to room temperature.

8.3.4.5 Fire residues shall be protected to prevent adverse reactions and to prevent the formation of reactive or unstable compounds.

8.3.4.6 Fire residues shall be disposed of in accordance with federal, state, and local regulations.

8.3.4.7 When drums or tote bins of burning materials can be moved safely, they shall be moved away from processing equipment and out of buildings as rapidly as possible.

8.3.4.8 Processing Equipment.

8.3.4.8.1* When a fire occurs in processing equipment, material feed to the equipment shall be stopped.

8.3.4.8.2 The equipment shall be kept in operation, unless continued operation will spread the fire.

8.3.4.9 Alkali Metals Fire-Fighting Procedures.

8.3.4.9.1* While an alkali-metal fire is being fought, every effort shall be made to avoid splattering the burning alkali metals.

8.3.4.9.2* Once the fire is extinguished and a crust is formed, the crust shall not be disturbed until the residues have cooled to room temperature.

8.3.5 Fire-Fighting Organization.

8.3.5.1 Only trained personnel shall be permitted to engage in fire control activity.

8.3.5.1.1 Personnel other than trained personnel shall be evacuated from the area.

8.3.5.1.2 Training shall emphasize the different types of fires anticipated and the appropriate agents and techniques to be used.

8.3.5.2 Fire-fighting personnel shall be given training in the extinguishment of test fires set in a safe location away from manufacturing buildings.

8.3.5.2.1 Training shall include all possible contingencies.

8.3.5.2.2* If professional or volunteer fire fighters are admitted onto the property in the event of a fire emergency, their activity shall be directed by a unified incident command that includes knowledgeable plant personnel.

8.4 Emergency Preparedness.

8.4.1 Local emergency response agency notification shall be required for any operation storing or processing 2.27 kg (5 lb) or more of powder, dusts, fines, or alkali metal in any form or 227 kg (500 lb) or more of chips or turnings.

8.4.2* Because of the unique nature of combustible-metal fires, a comprehensive emergency preparedness plan shall be prepared and maintained by the facility owner or operator where combustible metals are processed, handled, used, or stored.

8.4.2.1 This plan shall be available on site to emergency responders.

8.4.2.2 The plan shall include specific actions in the event of a combustible metal fire and shall be coordinated with the facility management and emergency responders.

8.4.2.3 The plan shall address locations for remote shutoff of supply systems when any of the following are present:

- (1) Water (water from all types of sources)
- (2) Electrical materials
- (3) Flammable gases
- (4) Flammable liquids
- (5) Toxic materials
- (6) Other hazardous materials

8.4.2.4 The following information on the safe handling of combustible metal fires shall be provided for emergency preparedness planning:

- (1) Water, when applied to most burning combustible metals, results in an increase in burning intensity and possible explosion.
- (2) Water applied to alkali metals not involved in the fire will result in hazardous decomposition, ignition, or explosion.
- (3) Application of carbon dioxide on combustible-metal fire adds to the intensity of the burning. Most combustible metals ignite and burn in 100 percent carbon dioxide atmospheres. (See 8.3.3.)
- (4) Dry chemical extinguishers react with alkali metals and intensify the fire.
- (5) Dry chemical extinguishers utilized on non-alkali metal fires are ineffective in controlling the metal fire but might be effective where flammable or combustible liquids are used and the metal is not yet involved in the fire. (See 8.3.3.)
- (6) Halogenated extinguishing agents used on alkali metals can result in an explosion.

- (7) Halogenated extinguishing agents will have a detrimental effect on other combustible metal fires, with the decomposition producing hazardous by-products.
- (8) A primary metal fire displays intense orange-to-white flame and can be associated with a heavy or large production of white or gray smoke.
- (9) When water is applied to non-alkali combustible metal, it can disassociate to the basic compounds, oxygen and hydrogen. Similar results occur with carbon dioxide.
- (10) When water is applied to alkali metals, hydroxides and hydrogen are generated immediately.
- (11) Fires involving combustible metals that contain moisture exhibit more intense burning characteristics than dry product.
- (12) Extreme heat can be produced. For example, burning titanium and zirconium have the potential to produce temperatures in excess of 3857°C (7000°F) and 4690°C (8500°F), respectively.
- (13) Dusts, fines, and powders of combustible metals present an explosion hazard, especially in confined spaces.
- (14) Dusts, fines, and powders of titanium and zirconium present extreme hazards; zirconium powders have ignition temperatures as low as 20°C (68°F). Static electric charges can ignite some dusts and powders of titanium and zirconium.
- (15) Zirconium and titanium powder can exhibit pyrophoric characteristics.
- (16) Turnings and chips of combustible metals can ignite and burn with intensity, especially if coated with a petroleum-based oil, with some spontaneous combustion having been observed.
- (17) With the exception of alkali metals, the larger the product, the smaller the likelihood of ignition. Bars, ingots, heavy castings, and thick plates and sheets are virtually impossible to ignite and, in most cases, self-extinguish when the heat source is removed.
- (18) The sponge product of most combustible metals burns at a slower rate but still produces tremendous heat.
- (19) Burning combustible metals can extract moisture from concrete and similar products that can intensify burning and cause spalling and explosion of the products and spewing of chunks of concrete.
- (20) Burning metal destroys asphalt and extracts moisture from rock.
- (21) Most fires involving non-alkali combustible metals usually cannot be extinguished, and unless they are placed in an inert atmosphere of argon or helium, they can only be controlled.
- (22) Fires involving large quantities of metals should be allowed to cool for at least 24 hours prior to being disturbed to prevent re-ignition.
- (23) Fires will oxidize most metals and provide a protective covering limiting open burning.
- (24) Alkali metal fires can be extinguished with the suitable extinguishing agents correctly applied. (See 8.3.3.)
- (25) Combustible metal fines and powders that are stored and contain moisture can produce hydrogen gas.
- (26) Combustible metal fines and dusts that are reduced (not oxidized) and that come into contact with other metal oxides can result in thermite reactions.

8.4.3 Emergency procedures to be followed in case of fire or explosion shall be established.

8.4.4* All employees in areas handling metals in a combustible form shall be trained initially and annually in the following procedures:

- (1) All employees shall be carefully and thoroughly instructed by their supervisors regarding the hazards of their working environment and their behavior and procedures in case of fire or explosion.
- (2) All employees shall be trained in the means of safe and proper evacuation of work areas.
- (3) All employees shall be shown the location of electrical switches and alarms, first-aid equipment, safety equipment, and fire-extinguishing equipment.
- (4) Employees expected to utilize fire-extinguishing equipment on incipient fires shall receive training on proper utilization of equipment.
- (5) All employees shall be taught the permissible methods for fighting incipient fires and for isolating fires and initiating an emergency notification.
- (6) The hazards involved in causing dust clouds and the danger of applying liquids onto an incipient fire shall be reviewed and explained.
- (7) Equipment operation, start-up and shutdown, and response to upset conditions shall be reviewed and explained.
- (8) The necessity and functioning of fire and explosion protection systems shall be reviewed and explained.
- (9) Emergency response plans shall be reviewed and explained.
- (10) The importance of housekeeping in minimizing fire and explosion hazards shall be reviewed with and explained to employees.
- (11) The appropriate cleaning and dust removal methods for the metal(s) present shall be reviewed with and explained to employees.

8.4.5 Prior to the arrival of alkali metals on site, the local fire department shall be notified of the presence of water-reactive materials on site and shall be notified of the hazards of using water on alkali-metal fires.

8.4.6 Where combustible metal is collected or stored in containers, material-handling equipment with sufficient capability to remove any container from the immediate area in the case of an emergency shall be readily available.

8.4.7* Clothing Fires.

8.4.7.1 Emergency procedures for handling clothing fires shall be established.

8.4.7.2 If deluge showers are installed, they shall be located away from dry metal powder-processing and metal powder-handling areas.

8.5* Emergency Response.

8.5.1 The following list of actions to be performed as well as information regarding the hazards of combustible metals shall be provided to emergency responders for the safe handling of combustible metal fires:

- (1)* Perform a size-up, evaluation, and identification of metals involved in the fire.
- (2) Ensure control of utilities (e.g., water, gases, power, etc.) to affected areas.
- (3) Review safety data sheets (SDSs) for the involved products, and if available, contact those familiar with the product and hazards.

- (4) Evaluate whether the fire can be isolated safely and allowed to burn out.
- (5) Determine whether uninvolved product and exposures — other than alkali metals — can be protected by hose streams, after an adequate review has been completed to ensure any runoff from hose streams does not come into contact with burning or molten combustible metal.
- (6) Do not apply water to alkali metals in either a fire or nonfire situation.
- (7) Use an inert blanket, such as argon, helium, or nitrogen, if the fire is burning in a closed container, such as a dust collection system, to control the fire where an adequate delivery system is available and personnel safety is considered.
- (8) Evaluate the potential for explosion.
- (9) Use extreme caution with fires involving combustible-metal powders, dusts, and fines because of the possibility of explosions, especially if the product becomes airborne and there is an available ignition source.
- (10) Evaluate the control and shutdown of both domestic and fire protection water systems to prevent unintended contact of water with burning or molten combustible metal.
- (11) Use extinguishing agents that are compatible with the hazards present. (See 8.3.3.)
- (12) Use extinguishing agents for containment of small and incipient fires. (See 8.3.3.)
- (13)* Use extreme caution with fires involving large quantities of product within structures.
- (14) Most fires involving combustible metals cannot be extinguished in a manner other than by providing an inert atmosphere of argon or helium — and nitrogen for alkali metals or iron — if the product is dry.
- (15) Most fires can be controlled by application of argon or helium — or nitrogen for alkali metals or iron — or by the development of an oxide crust.
- (16) The temperature of the metals involved in the fire can remain extremely high and the fire can flare up again if the product is disturbed prior to complete oxidation of the product or self-extinguishment.
- (17) Water in contact with molten combustible metals will result in violent steam explosions, and can cause hydrogen explosions and reactions.
- (18) Isolate the metal as much as possible; large fires might be impossible to extinguish.
- (19) Evaluate whether there is adequate drainage to prevent the contact of water with burning metal that is not compatible for protecting exposures.
- (20) Evaluate the fire to determine whether the fire can burn itself out naturally to minimize hazards to personnel and losses to exposures.

Chapter 9 Housekeeping

9.1 Retroactivity. The requirements this chapter shall apply to new and existing facilities.

9.2 Applicability. The requirements of this chapter shall not apply to nanometals (see Chapter 12).

9.3* Housekeeping Plan.

9.3.1 A documented housekeeping program shall be established.

9.3.2 Corrective actions shall be tracked for identified issues from the housekeeping program to ensure completion.

9.3.3 Procedures for unscheduled housekeeping of **unplanned** or accidental spillage of combustible metal dusts in operating areas shall be established as a part of a housekeeping plan.

9.4 Cleanup Procedures for Fugitive Dust Accumulations.

9.4.1* Fugitive dust shall not be allowed to accumulate to a level that obscures the color of the surface beneath it.

9.4.2* It shall be permissible to establish, in a building or room, an alternate housekeeping dust accumulation threshold based on a documented hazard assessment acceptable to the AHJ.

9.4.3 Periodic cleanup of fugitive dusts shall be accomplished by using one of the following:

- (1) Conductive, nonsparking scoops and soft brooms
- (2) Brushes that have natural fiber bristles
- (3) Dedicated vacuum cleaning systems designed for handling combustible metal powders in accordance with **Section 9.6**

9.4.4 Special attention shall be paid to areas utilizing powder for accumulations in crevices and joints between walls, ceilings, and floors.

9.4.5 Systematic cleaning of areas containing dust-producing equipment, including roof members, pipes, conduits, and other components, shall be conducted as frequently as conditions warrant.

9.4.5.1 The cleaning shall include machinery.

9.4.5.2 Cleaning methods shall be limited to those methods that minimize the probability of fire or explosion, as determined by a person knowledgeable in the properties of combustible-metal dusts.

9.4.5.3 Chips or powder sweepings shall be removed to a designated storage or disposal area.

9.4.5.4 Potential ignition sources associated with the operation of equipment during the cleaning operation shall be reviewed, and appropriate actions to isolate, eliminate, or minimize the potential hazards shall be taken.

9.4.5.5 Collected dust and fines shall be removed to a safe storage or disposal area.

9.5* Cleanup of Spilled Dust, Fine or Powder.

9.5.1 Preliminary cleanup of the bulk of the spilled powder shall be accomplished by using conductive, nonsparking scoops and soft brooms as well as brushes that have natural fiber bristles.

9.5.2 Vacuum cleaners shall be permitted to be used only for residual amounts of material remaining after preliminary cleanup.

9.5.3 Compressed-air blowdown shall be permitted as a method for cleaning only when done in accordance with **Section 9.7**.

9.6* Vacuum Cleaning.

9.6.1 Vacuum cleaning systems shall be used only for removal of dust accumulations too small, too dispersed, or too inaccessible to be thoroughly removed by hand brushing.

9.6.2* Vacuum cleaning systems shall be effectively bonded and grounded to minimize the accumulation of static electric charge.

9.6.3* Due to the inherent hazards associated with the use of **centralized** and portable vacuum cleaning systems for finely divided combustible metal dust, special engineering consideration shall be given to the design, installation, maintenance, and use of such systems. (See **Section 11.4**.)

9.6.4* When being used for combustible metal powder, portable vacuum cleaners shall be used only if listed for the material being vacuumed with the following conditions:

- (1) They shall be permitted only for small amounts of residual material remaining after preliminary cleanup.
- (2) They shall be emptied at the end of each operational period or shift.
- (3) They shall not be used as primary dust collectors.

9.6.5* When a vacuum cleaner is used for other materials, the equipment shall be thoroughly cleaned prior to use and identified accordingly.

Δ 9.6.6 Vacuum cleaner hose shall be conductive and nozzles or fittings shall be made of conductive, nonsparking material.

9.6.7 Assembled components shall be conductive and bonded where necessary.

9.6.8 Periodic tests for continuity shall be performed.

9.6.9 Combustible metal dust picked up by a **centralized** vacuum cleaning system shall be discharged into a container or collector located outside the building.

9.6.10 Sludge from dust collectors and vacuum cleaning system precipitators shall be removed weekly as a minimum and when equipment is shut down after use.

9.7 Compressed Air Cleaning Requirements.

9.7.1 Compressed air blowdown shall be permitted in areas that are otherwise impossible to clean by vacuuming or other means and shall be performed under carefully controlled conditions with all potential ignition sources prohibited in or near the area and with all equipment shut down.

9.7.1.1 Vigorous sweeping or blowing down with compressed air produces dust clouds and shall be permitted only where the following requirements are met:

- (1) Electrical equipment not suitable for Class II, **Division Group E or Zone Group IIIC** locations and other sources of ignition shall be shut down or removed from the area.
- (2) Compressed air shall not exceed a gauge pressure of 206 kPa (30 psi), unless otherwise determined to be safe by a documented hazard analysis.

9.7.2 To prevent potential explosions caused by the inadvertent use of high-pressure compressed air in place of low-pressure inert gas, fittings used on outlets of compressed-air and inert-gas lines shall not be interchangeable.

9.8 Water-Cleaning Requirements.

9.8.1 The use of water for cleaning shall not be permitted in manufacturing areas unless the following requirements are met:

- (1) Competent technical personnel have determined that the use of water will be the safest method of cleaning in the shortest exposure time.
- (2) Operating management has full knowledge of and has granted approval of its use.
- (3) Ventilation, either natural or forced, is available to maintain the hydrogen concentration safely below the lower flammable limit (LFL)
- (4) Complete drainage of all water effluent to a safe, contained area is available

9.8.2 Water-cleaning shall not be permitted in areas that have exposed alkali or water reactive materials.

9.8.3 Hose used for cleaning and wash down purposes shall be pressurized only while in active use for cleaning and wash down purposes.

9.9 Cleaning Frequency.

9.9.1* The accumulation of excessive dust on any portions of buildings or machinery not regularly cleaned in daily operations shall be minimized.

9.9.2 Regular, periodic cleaning of combustible metal dust and fines from buildings and machinery including roof members, pipes, conduits, and so on, shall be carried out as frequently as conditions warrant, based on visual inspections.

9.9.3* The housekeeping frequency shall be established to ensure that the accumulated dust levels on walls, floors, and horizontal surfaces, such as equipment, ducts, pipes, conduits, hoods, ledges, beams, roof members, and above suspended ceilings and other concealed areas, such as the interior of electrical enclosures, does not exceed the threshold accumulation.

9.9.4 Collected fugitive metal dust shall be removed to a designated storage or disposal area.

9.10 General Precautions.

9.10.1 Supplies of production materials in processing areas shall be limited to the amounts necessary for normal operations.

9.10.2 Ordinary combustible materials, such as paper, wood, cartons, and packing material, shall not be stored or allowed to accumulate in combustible metals processing areas unless necessary for the process and then only in designated areas.

9.10.3 Oil spills shall be cleaned up promptly.

9.10.4 Supplies shall be stored in an orderly manner with properly maintained aisles to allow routine inspection and segregation of incompatible materials.

9.10.5 Except for alkali metals, floor sweepings from combustible-metal-dust operations shall be permitted to contain small amounts of ordinary combustible materials.

9.10.6 The review of the hazards associated with cleaning operations shall include isolation, minimization, and elimination of the hazards.

9.10.7 In aluminum powder-handling or manufacturing buildings and in the operation of powder-conveying systems,

precautions shall be taken to avoid the production of sparks from static electricity; electrical faults; impact, such as iron or steel articles on each other, on stones, or on concrete; frictional heating; or other energy sources.

Chapter 10 Control of Ignition Sources

10.1* Retroactivity. Unless otherwise specified, the requirements of this chapter shall be applied retroactively.

10.2* Hot Work.

10.2.1 Hot work operations in facilities covered by this standard shall comply with the requirements of NFPA 51B and this section.

10.2.2 Hot work permits shall be required in any areas that contain metals in a combustible form.

10.2.3 Open flames, cutting or welding operations, propellant-actuated tools, and spark-producing operations shall not be permitted in areas where combustible metals are produced, stored, handled, or processed, including disposal areas, unless hot work procedures approved by qualified personnel are followed.

10.2.4 All hot work areas that require a permit shall be thoroughly cleaned of exposed metals in a combustible form before hot work is performed.

10.2.5 All internal sections of grinding equipment, ducts, and dust collectors shall be completely free of moist or dry metals in a combustible form and shall be purged before hot work is performed.

10.2.6 Hot work that is an integral step in a manufacturing process, is routine in nature, and has been reviewed as part of the hazard analysis shall not require a hot work permit.

10.3 Smoking.

10.3.1* Smoking shall not be permitted in areas where metals in a combustible form are present.

10.3.2 Smoking materials, matches, and lighters shall not be carried or used by employees or visitors in areas where metals in a combustible form are present.

10.3.3 Smoking shall be permitted only in designated areas.

10.3.4 No-smoking areas shall be posted with "No Smoking" signs.

10.3.5 Where smoking is prohibited throughout an entire plant, the use of signage shall be at the discretion of the facility management.

10.4 Spark-Resistant Tools.

10.4.1* Where tools and utensils are used in areas handling metals in a combustible form with minimum ignition energy less than 30 mJ or in a hybrid mixture, consideration shall be given to the risks associated with generating impact sparks and static electricity.

10.4.2* Tools including but not limited to scoops, shovels, and scrapers, used in the handling of metals in a combustible form shall be electrically conductive, bonded, and grounded, and shall be made of spark-resistant materials.

10.4.3 Spark-resistant tools shall be used when repairs or adjustments are made on or around any machinery or apparatus where metals in a combustible form are present and cannot be removed.

10.5* Static Electricity.

10.5.1* All permanently installed process equipment and all building structural steel shall be grounded and bonded by permanent ground wires to prevent accumulation of static electricity.

N 10.5.1.1 Grounding and bonding of equipment shall be independent of the facility electrical system.

N 10.5.1.2* Where nonconductive components present a discontinuity in the electrical path, isolated conductive components shall be bonded.

Δ 10.5.2* Movable or mobile process equipment or tools of metal construction shall be bonded or grounded or both, prior to use.

10.5.3* A monitoring and testing schedule shall be established based on the requirements of Section 6.2 to ensure that the effectiveness of grounding and bonding of fixed and mobile equipment has not failed or deteriorated over time and use.

10.5.4 Static dissipative belts shall be used on belt-driven equipment.

Δ 10.5.5 Bonding and grounding for dust collection and pneumatic conveying shall be in accordance with Chapter 11.

10.5.6* Grounding of Personnel.

10.5.6.1 Personnel involved in manually filling or emptying containers or vessels, or handling open containers of metals in a combustible form, shall be grounded during such operations.

10.5.6.2 Personnel grounding shall not be required where both of the following conditions are met:

- (1)* Flammable gases, vapors, and hybrid mixtures are not present.
- (2)* The minimum ignition energy (MIE) of the dust cloud is greater than 30 mJ.

10.6 Control of Friction Hazards. All machinery shall be installed and maintained in such a manner that the possibility of friction sparks is minimized.

10.6.1 Bearings.

10.6.1.1 Ball or roller bearings shall be sealed against dust.

10.6.1.2 Where exposed bearings are used, the bearings shall be protected to prevent ingress of combustible metal dust and shall have a lubrication program.

10.6.1.3 Clearances between moving surfaces that are exposed to paste, powder, or dust shall be maintained to prevent rubbing or jamming.

10.6.1.4 Localized frictional heating of bearings in any machine shall be minimized.

10.6.1.5 Grounded and bonded bearings shall be used.

10.6.1.6 Bearings of wet mills shall be grounded across the lubricating film by use of current collector brushes, a conductive lubricant, or other applicable means.

10.6.2 Fan and Blower Construction.

10.6.2.1 This section shall not be required to be applied retroactively.

10.6.2.2* Fans and blowers used to move air or inert gas in conveying ducts shall be of spark-resistant design and compatible with the material to be conveyed.

10.6.2.3 The design of the fan or blower shall not allow the transported combustible metal powder to pass through the fan before entering the final collector, unless the combustible metal powder-conveying system is inerted.

10.6.2.4* Fans or blowers shall be equipped with ball or roller bearings.

10.6.2.4.1 Bearings shall be equipped with temperature indicating devices.

10.6.2.4.2 Bearings shall be arranged to sound an alarm in case of overheating.

10.6.2.5 Fans and blowers shall be electrically interlocked with powder-producing machinery so that the machines can operate only if the fans are operating.

10.6.3* Grinding Wheels.

10.6.3.1 Wheels used for grinding combustible metal castings shall be relocated for dressing.

10.6.3.2 If it is not feasible to move the grinding wheels to a safer location for dressing, the hoods shall be thoroughly cleaned or removed entirely before dressing operations are started, and all deposits of dust on and around the wheel shall be removed before, during, and after dressing.

10.7 Electrical Power and Control.

Δ 10.7.1 All electrical equipment and wiring shall be installed in accordance with *NFPA 70*.

Δ 10.7.2 All process equipment and all building steel shall be bonded and grounded in accordance with *NFPA 70*.

Δ 10.7.3 All manufacturing buildings shall be provided with emergency lighting systems in accordance with *NFPA 101*.

Δ 10.7.4 Control equipment, control rooms, and offices meeting the requirements of *NFPA 496* shall be permitted.

10.7.5 Preventive maintenance for electrical equipment shall be established commensurate with the environment and conditions.

10.7.6 One or more remotely located control stations shall be provided to allow the safe and selective shutdown of process equipment in an emergency.

10.7.7 Where process equipment presents a deflagration hazard to a normally unoccupied room or building, an interlock shall prevent process operation unless associated room doors are fully closed.

10.7.8 Where process equipment presents an internal deflagration hazard, an interlock shall prevent equipment operation unless associated access panels are fully closed.

10.8 Electrical Area Classification.

N 10.8.1* The identification of the possible presence and extent of combustible dust hazardous (classified) locations shall be made based on the criteria in Article 500 or 506 of *NFPA 70*.

N 10.8.2 All areas designated as hazardous (classified) locations shall be documented, and such documentation shall be maintained and preserved for access at the facility.

N 10.8.3 Electrical equipment and wiring within combustible dust locations shall comply with *NFPA 70*.

10.8.4* Preventive maintenance programs for electrical equipment and wiring in combustible dust locations shall include provisions to verify that dusttight electrical enclosures are not experiencing significant dust ingress.

10.8.5 Flashlights and other portable electrical equipment shall be identified for the locations where they are used.

• 10.9 Powered Industrial Trucks.

Δ 10.9.1 Where used, powered industrial trucks shall be selected and maintained in accordance with *NFPA 505*.

Δ 10.9.2* Where industrial trucks, in accordance with *NFPA 505*, are not commercially available, a documented risk assessment acceptable to the authority having jurisdiction shall be permitted to be used to specify the fire and explosion prevention features for the equipment used.

10.10 Propellant-Actuated Tools.

10.10.1* Propellant-actuated tools shall not be used in areas where a dust explosion can occur unless all machinery in the area is shut down and the area and machinery are properly cleaned.

10.10.2 Propellant-actuated tools shall be used in accordance with Section 10.2.

Chapter 11 Powder and Dust Collection and Centralized Vacuum Systems

N 11.1 Retroactivity. Paragraphs 11.2.4.2.2, 11.2.4.4.6, 11.2.4.4.12, 11.2.4.4.15.3, 11.2.4.5.9, and Section 11.4 shall be applied retroactively.

N 11.2* Dust Collection.

N 11.2.1* Dust collection systems for machining, fabrication, finishing, mechanical conveying, additive manufacturing, and other dust generation operations for metals in a combustible form shall comply with the requirements of this chapter.

N 11.2.2 Powder conveying and collection for combustible metal powder production operations shall follow the requirements of Section 11.5, 11.2.4.4, and 11.2.4.5 for wet and dry AMS.

N 11.2.3 General Requirements.

N 11.2.3.1 All dust collection systems shall be installed in accordance with *NFPA 91*.

N 11.2.3.2* Where used to handle combustible particulate solids, systems shall be designed by and installed under the supervision of qualified persons who are knowledgeable about these systems and their associated hazards. [652:8.3.3.1.1]

N 11.2.3.3* Where it is necessary to make changes to an existing system, all changes shall be managed in accordance with the management of change (MOC) requirements in Section 4.4.

N 11.2.3.4* The dust collection system shall be designed and maintained to ensure that the air/gas velocity used meets or exceeds the minimum required to keep the interior surfaces of all piping or ducting free of accumulations under all normal operating modes.

N 11.2.3.5 Restrictions on Collected Materials.

N 11.2.3.5.1 Dust collection systems shall not be used to collect incompatible materials or other materials that might react with the conveyed metal dusts or particles.

N 11.2.3.5.1.1 The collection of any metal other than the metal the system was designed to collect shall be prohibited.

N 11.2.3.5.1.2 If other materials are to be collected, the modified process shall first be reviewed under management of change (MOC) to ensure that the requirements of this chapter are maintained.

N 11.2.3.6 Operations.

N 11.2.3.6.1 Sequence of Operation. Dust collection systems shall be designed with the operating logic, sequencing, and timing outlined in 11.2.3.6.1.1 and 11.2.3.6.1.2.

N 11.2.3.6.1.1 Startup. Dust collection systems shall be designed such that, on startup, the system achieves and maintains design air velocity prior to the admission of material into the system.

N 11.2.3.6.1.2 Shutdown.

N (A) Dust collection systems shall be designed such that, on normal shutdown, the system maintains design air velocity until material is purged from the ducting.

N (B) The requirements of 11.2.3.6.1.2(A) shall not apply during emergency shutdown of the system, such as by activation of an emergency stop button or by activation of an automatic safety interlocking device.

N 11.2.3.6.2* At each collection point, the system shall be designed to achieve the minimum velocity required for capture, control, and containment of the dust source. [652:8.3.3.3.1]

N 11.2.3.6.3* The hood or pickup point for each dust source shall have a documented minimum air volume flow based upon the system design. [652:8.3.3.3.2]

N 11.2.3.6.4* Branch lines shall not be disconnected, and unused portions of the system shall not be blanked off without providing a means to maintain required and balanced airflow. [652:8.3.3.3.3]

N 11.2.3.6.5* The addition of branch lines shall not be made to an existing system without first confirming that the entire system will maintain the required and balanced airflow. [652:8.3.3.3.4]

N 11.2.3.6.6* All dust sources (i.e., hoods) shall be connected using only a tapered main design.

N 11.2.3.6.7* Dust collection systems that remove material from operations that generate sparks, hot material, or similar ignition sources under normal operating conditions shall utilize a wet-type AMS and shall provide deflagration isolation to

prevent propagation between interconnected equipment in accordance with NFPA 69.

N 11.2.3.6.8* The air-material separator (AMS) selected for the system shall be designed to allow for the characteristics of the combustible dust being separated from the air or gas flow. [652:8.3.3.3.6]

N 11.2.3.6.9* Air-moving devices (AMDs) shall be of appropriate type and sufficient capacity to maintain the required rate of air/gas flow in all parts of the system.

N 11.2.3.6.10* All dust collection systems for combustible metal dusts shall have the AMD located on the clean side of the AMS.

N 11.2.3.6.11* Control panels and related equipment for controlling the operation of the AMS, AMD, monitoring equipment, or a combination thereof shall be installed in a location that is safe from the effects of a deflagration in the AMS.

N 11.2.3.6.12* The dust loading (i.e., grain loading) in ductwork during normal operating conditions shall be held below the minimum explosible concentration (MEC) in accordance with the deflagration prevention by combustible concentration reduction methods in NFPA 69.

N 11.2.3.7* The dry-type AMS and upstream work stations shall include a data plate listing the type of combustible metal dust that the system is designed to collect and a visible warning label that states collecting other materials can create a fire or explosion hazard.

N 11.2.3.7.1 The data plate on the dry-type AMS shall include the following information:

- (1) The metal collected by the AMS
- (2) The maximum P_{max} and K_{st} of dust that can be collected by the AMS
- (3) The lowest value of minimum ignition energy of the dust that can be collected by the AMS
- (4) Where filter media is used, the specifications of the filters that must be used

N 11.2.4 Specific Requirements.

N 11.2.4.1* A means shall be provided to prevent condensation in the ductwork.

N 11.2.4.2* Prevention of Static Discharge.

N 11.2.4.2.1 Prevention of ignition due to static discharge shall be in accordance with Section 10.5.

N 11.2.4.2.2 Bonding and Grounding.

N 11.2.4.2.2.1 All components of dust collection systems shall be bonded and grounded independently of the electrical grounding system to minimize accumulation of static electric charge.

N 11.2.4.2.2.2 When continuous contact is interrupted, metallic jumpers shall be installed for effective bonding.

N 11.2.4.2.2.3* The owner/operator shall verify and document the continuity of the bonding and grounding of the dust collection system on at least an annual basis.

N 11.2.4.3 Ducts, Ductwork, and Flex Connections.

N 11.2.4.3.1 All ducts and ductwork shall be constructed of metal or noncombustible conductive material.

N 11.2.4.3.2* Ducting runs shall be as short as practical with minimal turns.

N 11.2.4.3.3* Where the conveying duct is exposed to weather or moisture, it shall be moisture- and weathertight.

N 11.2.4.3.4* Hose and flexible connection length shall be the minimum required to accomplish the reason for their use.

N 11.2.4.3.5* All hoses and flex connections shall be conductive, static dissipative, or otherwise properly bonded/grounded to prevent accumulation of electrostatic charges.

N 11.2.4.3.6 Grinding operations shall not be served by the same dust collection system as buffing and polishing operations.

N 11.2.4.4* Dry-Type Air-Material Separator (AMS) Requirements.

N 11.2.4.4.1* Dry-type filter media AMS shall not be used for metal dusts being collected in air with a K_{st} greater than 150 bar-m/s or for niobium, tantalum, titanium, zirconium, and hafnium unless their use is supported by a dust hazard analysis (DHA) that is acceptable to the AHJ.

N 11.2.4.4.2 Media dust collectors shall be provided with all of the following ignition prevention measures:

- (1) Where the minimum ignition energy of the dust is less than 1000 mJ, the filter media shall be static-dissipative and shall be effectively bonded to the conductive filter frame.
- (2) Accumulations on filter media shall be limited to levels below the thresholds for any oxidative self-heating ignition and any possible ignition due to exothermic reaction with humid air. These thresholds shall be determined as part of the dust collection dust hazard analysis (DHA) conducted in accordance with Chapter 7.
- (3) Accumulation levels during the operation shall be monitored across the media by pressure drop or an equivalent sensor; if the accumulation exceeds the predetermined limits, a controlled shutdown of the collector and dust generation equipment shall be implemented.
- (4) Periodic inspections and replacement of media shall be based on intervals determined by the pressure drop across the filter media or by indication of self-heating detection equipment based on moisture reactivity.

N 11.2.4.4.3* The ingress, accumulation, or condensation of water in a dry-type AMS shall be prevented.

N 11.2.4.4.4 Dry-Type AMS Limitations.

N 11.2.4.4.4.1* Electrostatic collectors shall be prohibited.

N 11.2.4.4.4.2 Enclosureless dry-type AMS shall be prohibited.

N 11.2.4.4.4.3* Self-contained, dry-type AMS, down-draft benches, and environmental control booths (e.g., buffing, grinding, and finishing booths) with integral filter media in the wall shall be prohibited.

N (A) Self-contained, dry-type AMS, down-draft benches, and environmental control booths (e.g., buffing, grinding, and finishing booths) with integral filter media in the wall shall be permitted where a DHA has been performed and less than 0.22 kg (0.5 lb) of dust less than 500 microns is collected and emptied each day.

N (B) Self-contained, dry-type AMS devices, down-draft benches, and environmental control booths (e.g., buffing, grinding, and

finishing booths) with integral filter media in the wall shall be permitted where a DHA has been performed and less than 0.22 kg (0.5 lb) of dust less than 500 microns is collected and emptied each day.

N 11.2.4.4.5* The accumulation of material inside any area of the dry-type AMS other than the discharge containers designed for that purpose and for normal operation of the AMS shall not be permitted.

N 11.2.4.4.6 Repairs.

N 11.2.4.4.6.1 Where repairs on dry-type AMS are necessary, the AMS shall be emptied and residual accumulations of dust thoroughly removed before the repairs are made.

N 11.2.4.4.6.2 Ductwork leading into the AMS shall be disconnected and blanked off before repair work shall be permitted to be started.

N 11.2.4.4.7 Cyclone Construction.

N 11.2.4.4.7.1 Cyclone dry-type AMS shall be of conductive nonsparking construction suitable for the service intended.

N 11.2.4.4.7.2 Metallic cyclone dry-type AMS shall be continuously welded with smooth internal seams.

N 11.2.4.4.8 Temperature Monitoring Requirements.

N 11.2.4.4.8.1 Dry-type AMS shall be equipped with instruments for recording the surface temperature.

N 11.2.4.4.8.2 An overheating alarm or warning device shall be included, and the limit setting shall be below the maximum service temperature of the filter media or 50°C (122°F) below the hot surface ignition temperature of the dust, whichever is lower.

N 11.2.4.4.8.3 The devices specified shall give audible and visual alarms at normally attended stations.

N 11.2.4.4.9* Removal and replacement of filter media containing combustible dust shall be performed based on a standardized procedure that addresses the hazard of the combustible dust, work methods, and personal protective equipment.

N 11.2.4.4.10 Filter Media Properties.

N 11.2.4.4.10.1* Cartridge filters shall not be used with pyrophoric metal dusts.

N 11.2.4.4.10.2 Filter media shall not be chemically reactive with the collected dust, including any contaminants carried in the dust stream with the combustible metal.

N 11.2.4.4.11 Explosion Protection.

N 11.2.4.4.11.1 Where provided, explosion protection shall be directed to a safe location away from areas where personnel are normally present.

N 11.2.4.4.11.2 Collectors shall be protected by a minimum of one of the following explosion protection methods:

- (1)* Deflagration venting in accordance with NFPA 68, which includes the following requirements:
 - (a) Where deflagration venting is used on indoor dust collectors, the vents shall be ducted to the outside and the flow resistance shall be included in the vent design.

(b)* Vent ducts shall be designed to prevent accumulation of moisture.

(2) Oxidant concentration reduction in accordance with NFPA 69, which includes the following requirements:

(a) Where oxygen monitoring is used, it shall be installed in accordance with ISA 84.00.01, *Functional Safety: Application of Safety Instrumented Systems for the Process Industry Sector*.

(b)* Where the chemical properties of the material being conveyed require a minimum concentration of oxygen to control pyrophoricity, that level of concentration shall be maintained.

(3) Deflagration pressure containment in accordance with NFPA 69

(4)* Deflagration suppression in accordance with NFPA 69, where the suppressant has been shown to be chemically compatible and effective with the material collected

(5)* Dilution with a compatible, noncombustible material to render the mixture noncombustible

(6)* Deflagration venting through a listed dust retention and flame-arresting device that has been shown to be effective with the metal being collected through independent third-party testing

N 11.2.4.4.11.3 If the method in 11.2.4.4.11.2(5) is used, test data for specific dust and diluent combinations shall be provided and shall be acceptable to the authority having jurisdiction.

N 11.2.4.4.11.4 Where an explosion hazard exists and is not protected by 11.2.4.4.11.2(2) or 11.2.4.4.11.2(5), isolation devices that have been shown to be compatible and effective with the material collected shall be provided to prevent deflagration propagation between connected equipment in accordance with NFPA 69.

N (A)* Explosion isolation shall be provided in accordance with NFPA 69 between the dust collector and upstream process.

N (B) Where explosion isolation is not provided, a documented risk assessment acceptable to the authority having jurisdiction shall be permitted to be conducted to determine alternate protection methods.

N 11.2.4.4.11.5 The selection of the type and location of vents or weak sections of the collector shall be designed to minimize injury to personnel and to minimize blast and fire damage to nearby equipment or structures.

N 11.2.4.4.11.6 Where collectors are provided with deflagration vents, the area within the deflagration vent's discharge area shall be marked.

N 11.2.4.4.11.7 Signage shall be posted near the dust collector that reads, at a minimum, the following,

**CAUTION: THIS DUST COLLECTOR CAN CONTAIN
EXPLOSIBLE DUST.KEEP OUTSIDE THE MARKED AREA
WHILE EQUIPMENT IS OPERATING.**

N 11.2.4.4.11.8 Where collectors are provided with deflagration vents, vent closures shall be clearly marked with, at a minimum, the following text:

WARNING: EXPLOSION RELIEF DEVICE

N 11.2.4.4.12 Collected Material.

N 11.2.4.4.12.1 Discharge containers for collectors shall be emptied before or when 100 percent of the storage capacity of the container is attained.

N 11.2.4.4.12.2 Dust shall be removed from collectors at least once each day and at more frequent intervals if conditions warrant.

N 11.2.4.4.12.3 Material removed from the collector shall be permitted to be recycled into a process or mixed with an inert material in a volume ratio of five parts inert material to one part metal dust and, once mixed, shall be recycled or disposed of in accordance with local, state, and federal regulations.

N 11.2.4.4.12.4 Precautions shall be taken to avoid creating dust clouds when removing dust from the collectors.

N 11.2.4.4.12.5 The dust removed shall be recycled or disposed of in accordance with local, state, and federal regulations.

N 11.2.4.4.12.6 The dust shall be discharged into metal containers that shall be promptly and tightly covered to avoid the creation of airborne fugitive dust.

N 11.2.4.4.13* Requirements for the Clean Air Exhaust.

N 11.2.4.4.13.1 Recycling of exhaust air from fixed dry-type dust collectors into buildings shall not be permitted unless all of the following requirements are met:

- (1)* The material being collected has a calculated adiabatic flame temperature below 2300°C (4172°F).
- (2) Water has been shown to be an effective extinguishing agent for the material being collected.
- (3) Combustible or flammable gases or vapors are not present either in the intake or in the recycled air in concentrations above applicable industrial hygiene exposure limits or 1 percent of the LFL, whichever is lower.
- (4)* Combustible particulate solids are not present in the recycled air in concentrations above applicable industrial hygiene exposure limits or 15 mg/m³, whichever is lower.
- (5)* The oxygen concentration of the recycled air stream is between 19.5 percent and 23.5 percent by volume.
- (6) Provisions are incorporated to prevent transmission of flame and pressure effects from a deflagration in an AMS back to the facility unless a DHA indicates that those effects do not pose a threat to the facility or the occupants.
- (7) Provisions are incorporated to prevent transmission of smoke and flame from a fire in an AMS back to the facility unless a DHA indicates that those effects do not pose a threat to the facility or the occupants.
- (8) The system includes a method for detecting AMS malfunctions that would reduce collection efficiency and allow increases in the amount of combustible particulate solids returned to the building.
- (9) The building or room to which the recycled air is returned meets the housekeeping requirements of Chapter 9.
- (10) Recycled-air ducts are inspected and cleaned at least annually.

N 11.2.4.4.13.2 For materials not meeting items 11.2.4.4.13.1(1) and 11.2.4.4.13.1(2), they shall meet the following requirements prior to allowing the recirculation:

- (1) The maximum amount of metal in a combustible form accumulating in the discharge container will not exceed 4.5 kg (10 lb) of material with a maximum of 0.45 kg (1 lb) of material less than 500 microns for an aggregate of 4.95 kg (11 lb) total.
- (2) The collector annually collects a maximum of 300 lb of metal in a combustible form that is less than 500 microns.

N 11.2.4.4.14 Dry-type dust collectors shall be located outside of buildings unless permitted by 11.2.4.4.15.

N 11.2.4.4.15* Indoor Dry-Type Air-Material Separator (AMS). All portions of 11.2.4.4 on dry-type AMS requirements shall apply to indoor dry-type AMS in addition to this section.

N 11.2.4.4.15.1 A hazards analysis shall be conducted in accordance with Section 5.2 and Chapter 7 to ensure that the risk to personnel and operations is minimized for both new and existing systems.

N 11.2.4.4.15.2 The collector shall be designed to comply with all applicable requirements in this chapter.

N 11.2.4.4.15.3 The requirements for fire protection for indoor dry-type dust collection systems shall apply retroactively.

N (A) An automatic fixed fire suppression system shall be provided with a fire extinguishing agent that has been shown to be effective with the material collected for indoor collectors.

N (B) An automatic fixed fire suppression system shall not be required where the amount of material collected is less than 0.45 kg (1 lb) combustible metal and the dust collector is emptied after each day of operation.

N (C) Collected material shall not be stored in the collector, but shall be continually emptied from the collector into a sealed metal container through an isolation device in accordance with NFPA 69.

N (D) The collection of materials other than iron or steel dust shall be prohibited in collectors with a dirty volume greater than 0.57 m³ (20 ft³) or an airflow greater than 2549 m³/hr (1500 ft³/min).

N (E)* Media collectors shall contain a filter break (i.e., broken-bag) detection system that automatically shuts down the collector and connected equipment if a filter break is detected.

N 11.2.4.4.15.4* The exhaust duct from the fan discharge shall exit the building using as straight and short a path as is practical.

N 11.2.4.4.15.5* The collector inlet duct, exhaust duct, and blower shall be inspected at least every 6 months to ensure that material is not accumulating.

N 11.2.4.4.15.6 The collector exhaust duct located inside the building shall use one of the following deflagration protection methods:

- (1) Deflagration pressure containment in accordance with NFPA 69
- (2)* Deflagration isolation in accordance with NFPA 69

N 11.2.4.4.15.7* If the material meets either of the following criteria, the additional requirements in 11.2.4.4.15.7(A), 11.2.4.4.15.7(B), and 11.2.4.4.15.7(C) apply:

- (1) The material is a UN Class 4.3 solid as tested using UN 4.3 water reactivity test methods.
- (2)* Water has not been shown to be an effective extinguishing agent (*see Table A.8.3.3*).

N (A)* Media collectors shall include automatic cleaning of filters, and the pressure drop across the filter shall be continuously monitored and alarms activated if the pressure is outside of established operating ranges.

N (B) The collector shall contain a warning sign stating the following:

**THIS COLLECTOR CONTAINS COMBUSTIBLE METAL
DUST.DO NOT EXTINGUISH WITH WATER.**

N (C) The emergency response plan required in Section 8.5 shall include the following information to emergency responders:

- (1) Location of indoor dry-type dust collectors
- (2) Direction that the collector is not to be opened to extinguish a fire
- (3)* Direction that a fire in the collector is not to be extinguished with water
- (4) A description of the automatic fire extinguishing system on the collector
- (5) A list of effective extinguishing agents for the material being collected in the collector

N 11.2.4.4.15.8 Indoor dry-type dust collectors shall be permitted for metals covered by Chapter 16, meeting the following requirements:

- (1) The P_{\max} is less than 8 bar-g as measured using the test method in ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*.
- (2) The K_{st} is less than 150 bar-m/s as measured using the test method in ASTM E1226.
- (3) The minimum ignition energy (MIE) is greater than 100 mJ as measured using the test method in ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*.
- (4) The material is not a UN Class 4.2 solid as tested using UN 4.2 self-heating test methods.
- (5) The collection of materials other than iron or steel dust is prohibited in collectors with a dirty volume greater than 0.57 m³ (20 ft³) or an airflow greater than 2549 m³/hr (1500 ft³/min).

N 11.2.4.4.15.9 Indoor dry-type dust collectors shall be permitted for metals other than those covered by Chapter 16, provided that one of following provisions are met:

- (1) The maximum amount of metal in a combustible form accumulating in the collector receptacle shall not exceed a maximum accumulation of 4.5 kg (10 lb) of material greater than 500 microns with a maximum of 0.45 kg (1 lb) of material less than 500 microns for an aggregate of 5 kg (11 lb) total.
- (2) The collector annually collects a maximum of 136 kg (300 lb) of metal in a combustible form that is less than 500 microns.

- (3) The AMS has a dirty volume less than 0.2 m³ (8 ft³) or an airflow less than 850 m³/hr (500 ft³/min) and is emptied daily.

N 11.2.4.4.16* Portable Indoor Dry-Type Air-Material Separators (AMS) (Dust Collectors).

N 11.2.4.4.16.1 Portable indoor dry-type AMS shall be used only for grinding, buffing, or sanding operations.

N 11.2.4.4.16.2 Individual machines with portable dry dust-collection capabilities shall be permitted to be used indoors when the object being processed or finished is incapable of being moved to a properly arranged fixed hood or enclosure and shall incorporate the safeguards in 11.2.4.4.16.

N 11.2.4.4.16.3 Portable indoor dry-type dust collectors shall not be connected to a permanent fixed piping system.

N 11.2.4.4.16.4 The operation of portable dry dust-collection devices shall be subject to a DHA to ensure that the risk to personnel and operations from flash fire and shrapnel is minimized.

N (A)* The portable dust collector shall not be used in an identified deflagration hazard area until appropriate housekeeping methods in Chapter 9 have been used to remove hazardous quantities of dust.

N (B) Portable dry AMS with a dirty side volume greater than 0.2 m³ (8 ft³) shall be protected against explosion in accordance with NFPA 69.

N 11.2.4.4.16.5 Personal protective clothing shall comply with Section 4.6.

N 11.2.4.4.16.6 Prior to a change in the collected materials, the portable dry-type AMS and all associated components shall be thoroughly cleaned.

N 11.2.4.4.16.7 Grounding of personnel operating portable indoor dust collectors shall comply with 10.5.6.

N 11.2.4.4.16.8 The AMS and any associated components shall be bonded and grounded to an earth ground.

N 11.2.4.4.16.9 Hazards associated with static discharge shall be mitigated in accordance with Section 10.5.

N 11.2.4.4.16.10 Hoses shall be appropriate for use and be static dissipative or conductive.

N 11.2.4.4.16.11* Hoses and nozzles shall be bonded and grounded, and a path to ground shall be verified prior to use after each movement, each new connection, or both.

N 11.2.4.4.16.12 The resistance of the path to ground shall be documented and maintained.

N 11.2.4.4.16.13* The material collected shall be limited to 2.2 kg (5 lb) and, at a minimum, emptied daily.

N 11.2.4.4.16.14 The collector shall not be used on processes generating hot embers or sparks.

N 11.2.4.4.17 Operations Generating Hot Particles.

N 11.2.4.4.17.1* Grinding, plasma spray, and other operations generating hot metal particles shall have a spark arrestor system upstream of the AMS.

N 11.2.4.4.17.2* Dust collection systems for hot metallic nanoparticles shall be inerted unless combustibility testing of nano-

particle dust samples demonstrate that the particles are not pyrophoric.

N 11.2.4.4.17.3* Ordinary combustibles shall not be allowed to enter dust collection systems using dry-type AMS collecting hot metal particles.

N 11.2.4.4.17.4 Metal temperatures at the dust collector shall be compatible with the limiting temperature of the filter media.

N 11.2.4.5* Wet-Type Air-Material Separator (AMS) Requirements.

N 11.2.4.5.1 The exhaust vent shall terminate to a safe location outside the building and shall be securely fastened except as provided in 11.2.4.5.3.

N 11.2.4.5.2 The clean air shall not be permitted to be returned to an identified deflagration hazard area.

N 11.2.4.5.3 The cleaned air shall be permitted to be returned to the indoor work area when tests conducted prove that the collector's efficiency is great enough to provide, to both personnel and property, safety in the particular installation with regard to particulate matter in the cleaned air and accumulations of particulate matter and hydrogen in the work area.

N 11.2.4.5.4 The exhaust duct shall be as short and straight as is practical and shall be designed to withstand the same explosion pressure as the wet-type dust collector.

N 11.2.4.5.5* The outlet portion of the AMS and the exhaust vent duct shall be inspected and cleaned as required to prevent buildup of deposits of combustible metal dusts on the interior surfaces.

N 11.2.4.5.6* The wet-type AMS shall meet or exceed the design efficiency of combustible dust collection at all times during normal operation.

N 11.2.4.5.7 The use of additional dry filter media either downstream or combined with a wet collector shall not be permitted.

N 11.2.4.5.7.1 Where required to meet industrial hygiene exposure, dry filter media shall be permitted to be located downstream of the wet-type collector when equipped with all of the following:

- (1) Signs posted in the area warning of the hazards associated with the use of dry filter media
- (2) A differential pressure alarm
- (3) Static dissipative or conductive filter media
- (4) A means to limit hydrogen accumulation to 10 percent of the LFL
- (5) A high-temperature alarm at the filter media limit

N 11.2.4.5.8 Operational Safeguards.

N 11.2.4.5.8.1* The power supply to the dust-producing equipment shall be interlocked with the drive motor of the exhaust blower and the liquid-level, liquid-supply rate controller of the wet-type AMS, or both, to ensure that the system will shut down the equipment it serves if improper system function is detected.

N 11.2.4.5.8.2 A time delay switch or equivalent device shall be provided on the dust-producing equipment to prevent the start of the dust-producing process until the wet-type AMS and AMD are fully operational.

N 11.2.4.5.8.3 An interlock shall be provided to prevent operation of the wet-type AMS unless water tank capacity and water supply is maintained.

N 11.2.4.5.8.4 The AMS shall be constructed of conductive materials or be static dissipative.

N 11.2.4.5.9* Disposal of Sludge from Water-Based Wet-Type Air-Material Separators.

N 11.2.4.5.9.1* All sludge removed from wet-type AMS shall be collected and transported in covered, vented metal containers and removed daily, at a minimum, to a safe outdoor storage or ventilated disposal area.

N 11.2.4.5.9.2 Sludge from wet-type AMS shall be managed prior to disposal and recycled or disposed of in accordance with applicable federal, state, and local regulations.

N 11.2.4.5.9.3 Material removed from wet-type AMS shall be permitted to be mixed with an inert material (e.g., sand or material that is nonreactive with the combustible metal) in a volume ratio of at least five parts inert material to one part metal dust.

N 11.2.4.5.9.4 Smoking or open flames shall be prohibited in the disposal area and throughout the disposal process.

N 11.2.4.5.9.5 Open storage of sludge from wet-type AMS shall be isolated and segregated from other combustible materials and metal scrap to prevent propagation of a fire.

N 11.2.4.5.9.6 Sludge level buildup in the sludge tank of the wet-type AMS shall not exceed 5 percent of the tank liquid capacity as measured by volume.

N 11.2.4.5.10* Requirements to Prevent the Buildup of Hydrogen in Water-Based Wet-Type Air-Material Separators.

N 11.2.4.5.10.1 Wet-type AMS shall be designed so that hydrogen generated from the metal contacting the water is vented at all times.

N 11.2.4.5.10.2 Vents shall remain open and unobstructed when the machine is shut down.

N 11.2.4.5.10.3 When the AMS is not in operation, ventilation shall be permitted to be provided by an independent blower or by an unimpeded vent.

N 11.2.4.5.10.4 Each chamber of the AMS shall be vented to dissipate the hydrogen.

N 11.2.4.5.10.5 Sludge shall be removed from the AMS whenever the AMS is to remain inoperative for a period of 24 hours or more.

N 11.2.4.5.11 Additional Requirements for Water-Based Wet-Type AMS.

N 11.2.4.5.11.1 Where approved, the buildup of hydrogen in portable collectors shall be permitted to be mitigated through the use of an unimpeded vent in lieu of an auxiliary blower.

N 11.2.4.5.11.2 Hydrogen vents shall remain open and unobstructed when the machine is shut down.

N 11.2.4.5.11.3 When the dust collector is not in operation, ventilation shall be permitted to be provided by an independent blower or by an unimpeded vent.

- N 11.2.4.5.11.4** Hydrogen shall be permitted to be vented indoors where the DHA documents that this activity is acceptable and considers the effects of hydrogen buildup within the building.
- N 11.2.4.5.11.5** Each chamber of the collector shall be vented to dissipate the hydrogen.
- N 11.2.4.5.12 Additional Requirements for Non-Water-Based Wet-Type AMS.**
- N 11.2.4.5.12.1** The liquid used shall be limited to nonaqueous Class IIIB or noncombustible liquids.
- N 11.2.4.5.12.2** Possible vapor generation due to metal reaction with the liquid shall be evaluated and addressed as part of the DHA required in Chapter 7.
- N 11.2.4.5.12.3** Class IIIB liquids shall be handled in accordance with NFPA 30.
- N 11.2.4.5.12.4** Pressurized transfer of liquid shall be prohibited.
- N 11.2.4.5.12.5** Formation of liquid residue in the vicinity of the operating unit shall be minimized.
- N 11.2.4.5.13 Portable Indoor Wet-Type Immersion Air-Material Separators (AMS).**
- N 11.2.4.5.13.1** Portable indoor wet-type immersion AMS shall comply with 11.2.3.5 and 11.2.4.5.10.1 through 11.2.4.5.10.5, in addition to this section.
- N 11.2.4.5.13.2** Personal protective clothing shall comply with Section 4.6.
- N 11.2.4.5.13.3** When the collector is to remain inoperative for a period of 24 hours or more, sludge shall be removed from the collector or the collector shall be permitted to be moved to an approved safe location where hydrogen venting and other hazards are sufficiently mitigated.
- N 11.2.4.5.13.4** Hoses shall be appropriate for use and be static dissipative or conductive.
- N 11.2.4.5.13.5** Hoses and nozzles shall be bonded and grounded and shall include a monitoring system to confirm appropriate bonding and grounding. A path to ground shall be verified prior to each movement, prior to each new connection, or prior to both at least daily.
- N 11.2.4.5.13.6** The maximum capacity shall not exceed 20 lb (9 kg) of sludge.
- N 11.3* Centralized Vacuum Cleaning System.**
- N 11.3.1 General Requirements.**
- N 11.3.1.1*** Where used to handle combustible metal dusts, the system shall be designed by and installed under the supervision of qualified persons who are knowledgeable about this type of system and the associated hazards.
- N 11.3.1.2*** Where it is necessary to make changes to an existing system, all changes shall be managed in accordance with the management of change (MOC) policy.
- N 11.3.1.3*** The system shall be designed and maintained to ensure that the air-and-material velocity in the tubing, piping network, or both meets or exceeds the minimum required to keep the interior surfaces free of accumulations under all normal operational modes.
- N 11.3.2* Specific Requirements for Centralized Vacuum Cleaning Systems.**
- N 11.3.2.1*** The system shall be designed to assure minimum conveying velocities at all times whether the system is used with a single or multiple simultaneous operators.
- N 11.3.2.2*** The hose length and diameter shall be sized for the application and operation.
- N 11.3.2.3*** Vacuum cleaning tools shall be constructed of metal or shall be static dissipative and provide proper grounding and bonding to the hose.
- N 11.3.2.4*** Vacuum cleaning hose shall be static dissipative or conductive and shall be grounded.
- N 11.3.2.5** Centralized vacuum cleaning systems shall be used only for removal of dust accumulations too small, too dispersed, or too inaccessible to be thoroughly cleaned by hand brushing.
- N 11.3.2.6*** The entire centralized vacuum cleaning system shall be effectively bonded and grounded to minimize the accumulation of static electrical charge.
- N 11.3.2.7*** The tubing, piping, or both used in the system shall be metal and properly grounded and bonded.
- N 11.3.2.8*** The dry or wet AMS used in the system must comply with the requirements for dust collectors found in 11.2.4.4 for dry-type AMS and 11.2.4.5 for wet-type AMS.
- N 11.3.2.9*** The method of collected material discharge from a dry-type AMS shall be designed specifically for continuous discharge and for the characteristics of the combustible metal dust vacuumed into the system.
- N 11.4* Portable Vacuum Cleaners.**
- N 11.4.1** All dry-type AMS assemblies must comply with 11.2.4.4.16.
- N 11.4.2** All wet-type AMS assemblies must comply with 11.2.4.5.11 through 11.2.4.5.13.
- N 11.4.3*** When a portable vacuum cleaner is used for other materials, the equipment shall be thoroughly cleaned prior to use and identified accordingly.
- N 11.5 Pneumatic Conveying of Powder.**
- N 11.5.1 Ductwork for Pneumatic Conveying Systems.**
- N 11.5.1.1** Conveyor ducts shall be fabricated of spark-resistant metals that are compatible with the metal being transported.
- N 11.5.1.2** Plastics or other nonconductive ducts or duct liners shall not be used.
- N 11.5.1.3*** Ducts shall be electrically bonded and grounded to minimize accumulation of static electric charge.
- N 11.5.1.4*** Where the conveying duct is exposed to weather or moisture, it shall be moisture-tight.
- N 11.5.1.5*** A minimum conveying velocity shall be maintained throughout the conveying system to prevent the accumulation of dust at any point and to pick up any dust or powder that can drop out during unscheduled system stoppages.

N 11.5.1.6* Where a deflagration hazard exists, deflagration protection such as rupture diaphragms shall be provided on ductwork.

N 11.5.1.6.1 Deflagration vents shall relieve to a safe location outside the building.

N 11.5.1.6.1.1 Where provided with deflagration vents, the area within the deflagration vent's discharge area shall be marked.

N 11.5.1.6.1.2 It shall be permissible to determine the deflagration vent discharge area using NFPA 68.

N 11.5.1.6.1.3* Where ducts are provided with deflagration vents, vent closures shall be clearly marked as follows:

WARNING: EXPLOSION RELIEF DEVICE

N 11.5.1.6.2 Deflagration venting shall not be required for ductwork provided with explosion isolation systems identified in NFPA 69 that can prevent propagation of a deflagration into other parts of the process.

N 11.5.1.7* Whenever damage to other property or injury to personnel can result from the rupture of the ductwork, or where deflagration relief vents cannot provide sufficient pressure relief, the ductwork shall be designed in accordance with Chapter 13 of NFPA 69.

N 11.5.1.8 If a portion of the ductwork is located so that no damage to property or injury to personnel will result from its bursting, that portion shall be permitted to be of lightweight construction to intentionally fail, thereby acting as an auxiliary explosion vent for the system.

N 11.5.2 Conveying Using an Inert Medium.

N 11.5.2.1* Inert gas-conveying systems shall be permitted if designed in accordance with NFPA 69.

N 11.5.2.2 The inert gas used shall not react with the specific metal.

N 11.5.2.3* The concentration of oxygen in the inert gas stream shall be below the limiting oxygen concentration (LOC) of the specific gas in accordance with NFPA 69.

N 11.5.2.4* A residual level of oxygen below the LOC shall be present in the inert gas stream unless the conveyed material will not be exposed to air in future handling.

N 11.5.2.5 The oxygen concentration of the inert gas stream shall be monitored in accordance with NFPA 69.

N 11.5.2.6* The inert gas shall have a dew point so that no free moisture can condense or accumulate at any point in the system.

N 11.5.2.7* If the conveying gas is inducted into the system in a relatively warm environment and the ducts and collectors are relatively cold, the ducts and collectors shall be either insulated or provided with heating so that the gas temperature does not fall below the dew point, causing condensation.

N 11.5.2.8* A minimum conveying velocity shall be maintained throughout the conveying system to prevent the accumulation of dust at any point and to pick up any dust or powder that drops out during an unscheduled system stoppage.

N 11.5.3 Fan and Blower Construction and Arrangement.

N 11.5.3.1 Fans and blowers shall be in accordance with 10.6.2.

N 11.5.3.2 Personnel shall not be permitted within 15 m (50 ft) of the fan or blower while it is operating, except under either of the following conditions:

- (1) If personnel approach the fan or blower to perform a pressure test while the fan is operating, the test shall be done under the direct supervision of competent technical personnel, with the knowledge and approval of operating management, and with the flow of combustible metal powder cut off.
- (2) Where the combustible metal powder-conveying system is inerted, personnel shall be permitted to be closer than 15 m (50 ft).

N 11.5.3.3 No maintenance shall be performed on the fan until it is shut down.

N 11.5.3.4* Fans or blowers shall be located outside of all manufacturing buildings and shall be located to minimize entrance of dust into the building from the fan exhaust.

N 11.6 Powder Collection.

N 11.6.1* Collectors.

N 11.6.1.1 Dry-type collectors shall be located outside in a safe location and shall be provided with barriers or other means of protection for personnel.

N 11.6.1.2* The area around the collector shall be posted with a sign that reads as follows:

CAUTION: THIS COLLECTOR CAN CONTAIN EXPLOSIBLE DUST. KEEP OUTSIDE THE MARKED AREA WHILE EQUIPMENT IS OPERATING.

N 11.6.1.2.1 Where collectors are provided with deflagration vents, the area within the deflagration vent's discharge area shall be marked.

N 11.6.1.2.2* It shall be permissible to determine the deflagration vent discharge area using NFPA 68.

N 11.6.1.2.3 Where collectors are provided with deflagration vents, vent closures shall be clearly marked as follows:

WARNING: EXPLOSION RELIEF DEVICE

N 11.6.1.3 Collectors shall be constructed of metal that is static dissipative.

N 11.6.1.4 Ductwork shall comply with the provisions of 11.5.1.

N 11.6.1.5* The entire collection system, including the collector, shall be completely bonded and grounded to minimize accumulation of static electric charge.

N 11.6.1.6 Recycling of air from powder collectors into buildings shall be prohibited.

N 11.6.1.7* Where an explosion hazard exists, dry-type collectors shall be provided with deflagration vents.

N 11.6.1.7.1 Extreme care shall be taken in the selection of the type and location of vents or weak sections of the collector to minimize injury to personnel and blast damage to nearby equipment or structures.

N 11.6.1.7.2 Where collectors are provided with deflagration vents, the area within the deflagration vent's discharge area shall be marked.

N 11.6.1.7.3 It shall be permissible to determine the deflagration vent discharge area using NFPA 68.

N 11.6.1.7.4 Deflagration vents shall be positioned so that a potential blast is not directed toward any combustible or frangible structure.

N 11.6.1.7.5 Vent closures shall be clearly marked as follows:

WARNING: EXPLOSION RELIEF DEVICE

N 11.6.2 Repairs.

N 11.6.2.1 Where repairs on dry-type collectors are necessary, the collectors shall be emptied and residual accumulations of dust thoroughly removed.

N 11.6.2.2* Ductwork leading into the collector shall be disconnected and isolated by blanking before repair work is permitted to be started.

N 11.6.3 High-Temperature Warning.

N 11.6.3.1 Cyclone or other dry-type collectors shall be equipped with instruments for recording the surface temperature.

N 11.6.3.2 An overheating alarm or warning device shall be included, and the limit setting shall be below the maximum service temperature of the filter medium or 50°C (122°F) below the ignition temperature of the powder cloud, whichever is lower.

N 11.6.3.3 The devices specified in 11.6.3.2 shall give audible and visual alarms at normally attended locations.

N 11.6.4* Collector Filter Media. Collector filter media made from synthetic fabrics that accumulate static electric charges shall not be used.

N Chapter 12 Nanometal Powders

N 12.1 Retroactivity. The requirements of this chapter shall apply retroactively.

N 12.2* General.

N 12.2.1 Processing, handling, and storage of nanometal powders shall follow the requirements of this chapter in addition to the fire and explosion prevention and mitigation requirements in Chapters 8 through 16.

N 12.2.2* The requirements of this chapter are applicable to mixtures of nanometal powder particles and micrometer-sized metal particles where the nanometal powder particles are greater than 0.1 percent by weight.

N 12.2.3 If testing with a specific mixture and particle size distribution shows that the explosibility characteristics are similar to the micrometer metal particles, the requirements of this chapter do not apply.

N 12.2.4* Due to the special hazards of nanometals, a DHA conducted in accordance with Chapter 7 shall include a determination of the appropriate effective fire and explosion protection measures for combustible metal nanoparticle processes and equipment.

N 12.3 Nanoparticle Production Processes.

N 12.3.1 Nanometal Production Using Exploding Electrical Wires.

N 12.3.1.1* Fire, flash fire, and explosion hazards associated with exploding electrical wire production of nanometals, as well as the energy associated with the exploding wires, shall be assessed and documented.

N 12.3.1.2* Fire and explosion protection measures for this process equipment shall be established based on the hazard analysis, other pertinent requirements of this standard, and blast wave protection for the exploding wires.

N 12.3.1.3 The power supply and electrical circuits used for exploding electrical wire production shall be in accordance with NFPA 70.

N 12.3.1.4 If an inert gas atmosphere is used in the chamber containing the exploding wires, control of the maximum allowable oxygen concentration shall be in accordance with Chapter 7 of NFPA 69.

N 12.3.1.5 If a hydrogen atmosphere is used in the chamber containing the exploding wires, the generation and use of hydrogen shall be in accordance with NFPA 2.

N 12.3.2 Nanometal Production with Plasma-Based Processes.

N 12.3.2.1* Fire and explosion hazards associated with nanometal production by recondensation after metal immersion in a plasma, as well as the potential ignitions due to exposure to plasma thermal loads and ionized and aerosol particles, shall be assessed and documented.

N 12.3.2.1.1 Fire and explosion protection measures for this process shall be established based on the hazard analysis and the other pertinent requirements of this standard.

N 12.3.2.2 The internal surfaces of plasma-generating equipment shall be inspected after each production run to check for combustible metal particulate condensation and accumulation, and shall be cleaned where such condensation and accumulation is observed.

N 12.3.2.3 Particulate cooling, capture, and encapsulation equipment shall be operated per requirements in Section 12.4.

N 12.3.3 Nanometal Synthesis by Chemical Reduction of Salt Solutions and Colloidal Dispersions.

N 12.3.3.1* Fire and explosion hazards associated with nanometal production by chemical reduction methods, as well as the chemical reactivity hazards and the flammability properties of all reactants and reaction products, shall be assessed and documented.

N 12.3.3.2 Fire and explosion protection measures for this process shall be established based on the hazard analysis and the other pertinent requirements of this standard.

N 12.3.3.3* Fire protection for solutions with flammable or combustible liquid solvents shall be in accordance with requirements of NFPA 30.

N 12.3.4 Biochemical Production of Nanometals.

N 12.3.4.1* Fire and explosion hazards associated with nanometal production by biochemical processes, as well as the biochemical reactivity and flammability hazards and possible needs for biological or microbiological containment, shall be assessed and documented.

N 12.3.4.1.1 Fire and explosion protection measures for this process shall be established based on the hazard analysis and the other pertinent requirements of this standard.

N 12.3.5* Nanoparticle Production by Thermal Spray Pyrolysis.

Fire and explosion protection measures for combustible metal nanoparticle thermal spray pyrolysis production processes and equipment shall address the hazards of the materials coated by the nanoparticles, including the potential for pyrophoric reactions of the nanoparticles and coating upon suddenly being introduced to an air atmosphere.

N 12.4 Equipment Design and Operation.

N 12.4.1* Nanometal transport in pipes, ducts, and conveyors shall use an inert gas at an oxygen concentration below the limiting oxygen concentration (LOC) in accordance with NFPA 69. The LOC shall be measured specifically for submicron particulate of the primary metal transported.

N 12.4.2 Equipment with inerting for nanometals shall use an inert gas atmosphere in accordance with NFPA 69 and a LOC based on testing with an applicable nanometal sample.

N 12.4.3 Explosion suppression and isolation systems for nanometal explosion protection shall be in accordance with NFPA 69 and shall have been demonstrated to be effective for pertinent nanometals.

N 12.4.4* Equipment containing nanometals that are intended to withstand explosion pressures shall have a pressure containment capability in accordance with NFPA 69 and a value of P_{max} determined for a nanometal similar in composition and size to the nanometal in the equipment.

N 12.4.5 Equipment and operations for application of nanometal coatings with flammable or combustible solvents shall be protected in accordance with applicable requirements in NFPA 33 or NFPA 34.

N 12.5 Housekeeping.

N 12.5.1* A documented housekeeping program shall be established based on the hazards described in the DHA for all nanometal particles and shall include special provisions for preventing personnel exposure to nanoparticles during cleaning.

N 12.5.1.1 The location and extent of potential nanoparticle deposits shall be described in the program documentation.

N 12.5.1.2 The likelihood of ignition during cleaning shall also be documented.

N 12.5.2 Personnel responsible for cleaning nanoparticle deposits shall be equipped with personal protective equipment (PPE) determined as part of the documented housekeeping program.

N Chapter 13 Additive Manufacturing

N 13.1 Retroactivity. The requirements of this chapter shall apply retroactively.

N 13.2 General Requirements.

N 13.2.1* Due to the special hazards of additive manufacturing, a dust hazards analysis (DHA) conducted per Chapter 7 shall include the need for inerting, proper personal protective equipment (PPE), and other fire and explosion protection measures during all the operations delineated in Section 13.3.

N 13.2.2 Additive manufacturing facility construction and layout, including powder storage provisions, shall meet the requirements of Chapters 14 through 16 for all applicable metals in addition to the requirements of this chapter.

N 13.2.3* Operations having more than 22.7 kg (50 lb) in the system at any one time shall meet the requirements of 13.2.4.

N 13.2.4* Provisions for Emergency Shutdown for Large Systems.

N 13.2.4.1 The system shall shut down on any of the following conditions:

- (1) Loss of purge gas
- (2) High chamber temperature 50°C (90°F) above normal operating temperature
- (3) Loss of vacuum

N 13.2.4.2 The system shall be provided with an automatic emergency shutdown device.

N 13.2.4.3* The system shall also be provided with a local and a remote manual emergency shutdown device.

N 13.2.4.3.1 Shutdown shall deactivate the affected printing operations.

N 13.2.4.3.2 Shutdown shall not deactivate the purge gas or the vacuum system of the affected system.

N 13.2.5 Shipping and Handling Containers.

N 13.2.5.1* When nonmetallic containers or liners are used for powders, the containers or liners shall be conductive or static dissipative.

N 13.2.5.2* Where the requirement of 13.2.5.1 is not met, a documented risk assessment acceptable to the authority having jurisdiction shall be permitted to be conducted to determine the alternative mitigations to be implemented.

N 13.3 Additive Manufacturing Equipment and Operations.

N 13.3.1 General.

N 13.3.1.1 All pieces of fixed equipment shall be grounded and bonded in accordance with NFPA 77.

N 13.3.1.2 Personnel involved in manually filling or emptying containers or vessels, sieving, handling open containers, or cleaning shall be grounded/bonded during such operations.

N 13.3.2 Powder Weighing Operations.

N 13.3.2.1 Powder weighing equipment shall have an installed ground connection. (*See 7.4.1.3 and 10.1.1 in NFPA 77.*)

- N 13.3.2.2*** Conductive powder containers shall be bonded to the weighing equipment before the transfer of metallic powder to and from the weighing equipment.
- N 13.3.2.3** All containers or hoppers used for intermediate handling of materials shall be conductive.
- N 13.3.2.4*** Where the requirement of 13.3.2.3 is not met, a documented risk assessment acceptable to the authority having jurisdiction shall be permitted to be conducted to determine the alternative mitigations to be implemented.
- N 13.3.2.5*** Control measures shall be employed to avoid the formation of suspended dust clouds during transfer of powder to and from the weighing equipment.
- N 13.3.3 Sieving Operations.**
- N 13.3.3.1** Powder sieving equipment shall have an installed ground connection.
- N 13.3.3.2*** Conductive powder containers shall be bonded to the sieving equipment before the transfer of metallic powder to and from the sieving equipment.
- N 13.3.3.3** Containers or hoppers used for sieving operations materials shall be conductive.
- N 13.3.3.4*** Where the requirement of 13.3.3.3 is not met, a documented risk assessment acceptable to the authority having jurisdiction shall be permitted to be conducted to determine the alternative mitigations to be implemented.
- N 13.3.3.5*** Control measures shall be employed to avoid the formation of suspended dust clouds during transfer of powder to and from the sieving equipment.
- N 13.3.3.6*** Precautions shall be employed to remove tramp metal before it enters the sieve.
- N 13.3.4 Powder Transport Equipment.**
- N 13.3.4.1** Bonding and grounding connections shall be verified prior to the transfer of metallic powder to and from transport equipment.
- N 13.3.4.2*** Control measures shall be employed to avoid the formation of suspended dust clouds during transfer of powder.
- N 13.3.4.3** Transport containers shall be completely enclosed and sealed during transport.
- N 13.3.5 3D Printing.**
- N 13.3.5.1 Startup.**
- N 13.3.5.1.1*** Before starting printing operations, an inert environment shall be established at a concentration below the limiting oxidant concentration (LOC) for the alloy and size distribution being processed per NFPA 69. The LOC shall be determined for the inert gas being used.
- N 13.3.5.1.2** Inerting operations shall be in accordance with 11.5.2.2 through 11.5.2.8, and the inert gas supply shall be monitored per NFPA 69.
- N 13.3.5.1.3*** Before loading combustible metal powder into the printer, the operator shall verify that the printer and dust collector is free of residual materials from previous operations with other metal alloys, unless a DHA has determined that the materials are compatible under all conditions.
- N 13.3.5.1.4** Purged enclosures shall be in accordance with NFPA 496.
- N 13.3.5.2 Powder Bed Printing.**
- N 13.3.5.2.1** An inert environment shall be maintained at a concentration below the LOC for the alloy and size distribution being processed per NFPA 69. The LOC shall be determined for the inert gas being used.
- N 13.3.5.2.2** The inert gas supply shall be monitored per NFPA 69.
- N 13.3.5.2.3** Control measures shall be employed to minimize frictional heating of the powder.
- N 13.3.5.2.4** Powder shall be transported from the bed to the build platform without forming dust clouds.
- N 13.3.5.2.5** Loose powder and dust accumulations within the printer shall be prevented using inerted dust collectors or an alternate method acceptable to the authority having jurisdiction.
- N 13.3.5.2.5.1** In addition to the requirements in NFPA 69, inerting operations shall be in accordance with 11.5.2.2 through 11.5.2.8.
- N 13.3.5.3 Powder Spray Printing.**
- N 13.3.5.3.1** An inert environment shall be maintained around the powder spray at a concentration below the LOC for the alloy and size distribution being processed per NFPA 69.
- N 13.3.5.3.2** The inert gas supply shall be designed to ensure an envelope within the spray housing and on the build platform is maintained throughout the build process.
- N 13.3.5.3.3** The inert gas supply shall be monitored per NFPA 69.
- N 13.3.5.3.4** The powder spray equipment and operations shall be in accordance with applicable provisions of NFPA 33.
- N 13.3.5.3.5** Loose powder and dust accumulations within the printer shall be minimized using inerted dust collectors or an alternate method acceptable to the authority having jurisdiction.
- N 13.3.5.3.5.1** In addition to the requirements in NFPA 69, inerting operations shall be in accordance with 11.5.2.2 through 11.5.2.8.
- N 13.3.5.4 Object Harvesting.**
- N 13.3.5.4.1*** Printed object removal shall be performed without the formation of a dust cloud.
- N 13.3.5.5 Post Processing Operation.**
- N 13.3.5.5.1*** Loose powder shall be removed from the printed object before post processing.
- N 13.3.5.5.2** Dust generated during post processing shall be captured in accordance with Chapter 11.
- N 13.3.5.6 Fire Protection Systems.**
- N 13.3.5.6.1** Fire protection systems shall be in accordance with Chapter 8.

N 13.4 Equipment and Object Cleaning.

N 13.4.1 Equipment used for cleaning shall be listed for use in a Class II, Group E atmospheres.

N 13.4.2 Grounding and bonding of equipment used for cleaning shall be in accordance with the requirements of Chapter 11.

N 13.4.3 Proper PPE, including the need for flash-fire-resistant garments, shall be in accordance with Section 4.6.

N 13.4.4* Cleaning operations shall avoid the formation of dust clouds.

N 13.4.5 Electrical classification shall be in accordance with Section 10.8.

N 13.5* Training.

N 13.5.1* Operators shall be required to receive documented equipment manufacturer-representative-provided training classes addressing the safety and proper use of all additive manufacturing and cleaning equipment as described in equipment operation manuals.

N 13.5.1.1 Operators shall receive this training prior to production assignment.

N 13.5.1.2 Where these classes are not available, the owner/operator shall develop an equivalent training program based on the current manufacturer's recommendations and knowledgeable and experienced users.

N 13.5.2 In addition to the requirements of Chapter 8, operators shall be trained in accordance with Sections 9.8 of NFPA 652.

N 13.6 Emergency Response.

N 13.6.1 Emergency response shall be in accordance with Chapter 8 in addition to the equipment manufacturer's instructions.

N 13.6.2* Signs identifying the powder composition in the printer shall be posted in a location readily visible to emergency responders.

Chapter 14 Alkali Metals

14.1* General Provisions.

14.1.1 Retroactivity. The requirements of 14.1.2 through 14.1.4 shall apply to new and existing facilities.

14.1.2 Housekeeping.

14.1.2.1* Special Consideration. Alkali metals shall be kept away from sources of moisture.

14.1.3 Personal Protective Equipment (PPE). In addition to the requirements of this section, PPE shall be in accordance with Section 4.6.

14.1.3.1* PPE for Handling Solid Alkali Metals.

14.1.3.1.1 Personnel shall wear eye protection while handling solid alkali metals.

14.1.3.1.2 Personnel shall wear gloves while handling solid alkali metals.

14.1.3.1.3 Gloves shall have tight-fitting cuffs and shall be made of a material suitable for protection from caustic hazards.

14.1.3.1.4 Clothing worn by personnel handling solid alkali metals shall have no exposed pockets or cuffs that could trap and carry alkali metal residues.

14.1.3.2* PPE for Handling Molten Alkali Metals.

14.1.3.2.1 Personal protective equipment shall be worn and shall be compatible with the hazards of molten alkali metals.

14.1.3.2.2* An external clothing layer that is impervious to body moisture shall be worn for protection from splash.

14.1.4 Reactivity.

14.1.4.1* Thermite Reactions. Caution shall be exercised in the mixing of fines or molten material with metal oxides [e.g., iron oxide (rust)].

14.1.4.2 Eutectic Reactions. (Reserved)

14.1.5 Management of Change. Management of change shall be in accordance with Section 4.4.

14.1.6 Alternative Methodologies. (Reserved)

14.1.7 Test Results. (Reserved)

14.1.8 Other.

14.2* Facility Design Requirements.

14.2.1 Building Construction.

14.2.1.1 Section 14.2 shall apply to buildings or portions of buildings that are dedicated to the handling, processing, or storage of solid or molten alkali metal.

14.2.1.2 Noncombustible Materials.

14.2.1.2.1 Buildings dedicated to the storage, handling, processing, or use of alkali metals shall be constructed of noncombustible materials.

14.2.1.2.2 Construction of other than noncombustible materials shall be permitted if equivalent protection can be demonstrated.

Δ 14.2.1.3 Buildings shall comply with applicable provisions of NFPA 101.

14.2.1.4* Roof decks shall be watertight.

14.2.1.5 Walls and ceilings shall be constructed with noncombustible insulation that has been tested in accordance with ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*.

14.2.1.6* In areas where alkali metals are stored, handled, or processed, floors shall be a solid surface and shall be constructed with materials that are compatible and nonreactive with alkali metals and capable of providing containment of molten alkali metals resulting from fire.

14.2.1.7* Floor drains shall not be permitted.

14.2.1.8 Where molten alkali metals are handled, dispensed, or stored, the handling area shall be provided with compatible and nonreactive containment.

14.2.1.8.1 The containment shall provide for a volume of 110 percent of the maximum amount of material that is contained or could be spilled in the area.

14.2.1.8.2 In areas where molten alkali metals are handled, wall-to-floor connections shall be sealed against the penetration of molten alkali metals.

14.2.1.9 Separation from Water.

14.2.1.9.1* Nonprocess piping that can contain water or steam under normal use (e.g., domestic water pipes, roof drains, waste pipes) shall not be permitted in areas containing alkali metals.

14.2.1.9.1.1 Water pipes required for safety operations shall be permitted.

14.2.1.9.1.2 Piping permitted by **14.2.1.9.1.1** shall be equipped with an emergency shutoff that is identified and located outside the area.

14.2.1.9.1.3 Piping permitted by **14.2.1.9.1.1** shall be constructed of steel.

14.2.1.9.2 A sprinkler system(s) deemed appropriate in accordance with **8.3.2** shall be permitted.

14.2.1.9.3 Portions of buildings where alkali metals are stored, handled, processed, or used shall be separated by watertight walls, ceilings, and door systems from adjacent areas where water can be present.

14.2.1.9.4 The floor shall be sloped in such a manner to prevent water from entering the alkali metals area.

14.2.1.10* Ventilation.

14.2.1.10.1 Roof ventilation shall be provided for dissipation of hydrogen to the atmosphere for areas handling, processing, or storing alkali metals.

Δ 14.2.1.10.2 Mechanical ventilation systems shall be designed and installed in accordance with *NFPA 5000*.

14.2.1.11 NFPA Hazard Identification Markings.

Δ 14.2.1.11.1 Alkali metal handling, processing, and storage areas having quantities greater than 2.3 kg (5 lb) shall have diamond markings as specified in *NFPA 704* to make emergency responders aware of the presence of water-reactive materials within the area.

Δ 14.2.1.11.2 The diamond markings shall be at least 457.2 mm (18 in.) on each side with appropriate size numbers and symbols as specified in *NFPA 704*.

14.2.2 Fire Protection.

Δ 14.2.2.1 Fire Protection. Fire protection shall be established in accordance with Chapter **8**.

Δ 14.2.2.2* Because of the unique nature of alkali metal fires, a comprehensive fire protection plan shall be developed where alkali metal is processed, handled, used, or stored in accordance with Chapter **8**.

14.2.3 Dust Collection. (Reserved)

14.2.4 Hazard Analysis. The hazard analysis shall be in accordance with Section **4.5**.

14.3 Primary Metal Production.

14.3.1 Reduction. (Reserved)

14.3.2 Melting and Casting.

14.3.2.1* Mineral oils or organic materials shall not be used to protect potassium or NaK from moisture or oxygen.

14.3.2.2 Molten alkali metals shall be contained in closed systems that prevent contact with air or reactive materials, except as required for the process.

14.3.2.3 Molten alkali metal piping systems shall be designed in conformance with ANSI/ASME B31.3, *Process Piping Design*.

14.3.2.3.1 All pump seals and flange gaskets shall be made of compatible materials.

14.3.2.4 Molten alkali metal systems shall overflow or relieve to secondary containments designed to handle 110 percent of the largest expected failure and shall be provided with the means to prevent contact with incompatible materials, including moisture.

14.3.2.5 Molten alkali metals shall be handled in a detached building or in portions of a building separated from other exposures by fire-rated construction.

14.3.2.6 Where molten alkali metal is cast, molds, ladles, and other components that could come in contact with the molten alkali metal shall be free of incompatible materials, including moisture.

14.3.3 Refining. (Reserved)

14.4 Powder Production. (Reserved)

14.5 End Users of Powder. (Reserved)

14.6 Processing and Handling.

14.6.1 Machinery and Operations.

Δ 14.6.1.1* Where alkali metals are processed with a flammable or combustible liquid, the requirements of *NFPA 30* shall also be followed for the flammable or combustible liquids.

14.6.1.2 Moisture Protection.

14.6.1.2.1 Solid alkali metals shall be protected from moisture during handling.

14.6.1.2.2* Mineral oils or organic materials shall not be used to protect potassium or NaK from moisture or oxygen.

14.6.1.2.3* Only the amount of alkali metal needed for an individual task or procedure shall be removed from containers.

14.6.1.2.4* Surplus alkali metal shall be placed in a container protected from moisture and sealed immediately.

14.6.1.3 Machining and Operations. (Reserved)

14.6.2 Flake and Paste. (Reserved)

14.6.3 Plasma Spray Operations. (Reserved)

14.6.4 Transfer Operations.

14.6.4.1 General Precautions.

14.6.4.1.1 Alkali metals shall be handled only by trained personnel who are knowledgeable of the hazards associated with alkali metals.

14.6.4.1.2 The number of persons in alkali metal-handling areas during operations shall be limited to those necessary for the operation.

14.6.4.1.3 Access to alkali metal-handling areas by unauthorized personnel shall not be permitted.

14.6.4.1.4* Alkali metals shall not be handled in the presence of incompatible materials.

14.6.4.1.5 Dedicated storage of ordinary combustible materials or flammable or combustible liquids shall be prohibited in areas where alkali metals are handled, processed, or stored.

14.6.4.1.5.1 Quantities of dry mineral oil necessary for safe storage and handling shall be permitted where lithium is processed, handled, or stored.

14.6.4.1.6* Allowable Quantity. The quantity of alkali metals permitted in processing areas shall be limited to that necessary for operations, but it shall not exceed the quantity required for 1 day or as needed for batch processing.

14.6.5 Processing Recycled Material. (Reserved)

14.7* Machining, Fabrication, Finishing, and Media Blasting.

14.7.1 Hot Work Operations.

14.7.1.1 Hot work operations shall be in accordance with Section 10.2.

14.7.2 Chip Processing. (Reserved)

14.7.3 Dust Collection. (Reserved)

14.8 Storage and Handling.

14.8.1* Storage of Product.

14.8.1.1 Alkali metals shall be handled, processed, and stored only in accordance with the requirements of this chapter.

14.8.1.2 Storage of Solid or Molten Alkali Metals.

14.8.1.2.1 General Precautions.

14.8.1.2.1.1* Alkali metals shall be permitted to be stored in shipping containers that meet the requirements of UN “Recommendations for the Transport of Dangerous Goods: Model Regulations — Manual of Tests and Criteria” for the transportation of dangerous goods for alkali metals or in clean, moisture-free, compatible, and nonreactive metal-sealed containers dedicated for the storage of alkali metals.

14.8.1.2.1.2 Alkali metals shall not be stored in containers previously used for the storage of incompatible materials.

14.8.1.2.1.3* Alkali metals shall not be stored in an area with incompatible materials.

14.8.1.2.1.4 Alkali metals in nonbulk containers shall not be stored outside.

14.8.1.3 Solid Alkali Metals Storage.

14.8.1.3.1 Solid alkali metals shall be stored only on the ground floor.

14.8.1.3.2 There shall be no basement or depression below the alkali metals storage area into which water or molten metal could flow or fall during a fire.

14.8.1.3.3 The solid alkali metals storage area shall be isolated from water except for approved installation of automatic sprinkler systems for use in alkali metal storage.

14.8.1.3.4 Containers shall be stored individually or on pallets in an arrangement that allows visual inspection for container integrity.

14.8.1.3.4.1 Containers on pallets shall be permitted to be stored in racks not more than 4.5 m (15 ft) high.

14.8.1.3.4.2 Containers on pallets and not stored in racks shall be stacked in a stable manner not to exceed three pallets high.

14.8.1.3.4.3 Aisle widths shall be established and approved by the authority having jurisdiction to provide for access to and for the removal of materials during emergency situations.

14.8.1.3.4.4 Idle pallet storage shall not be permitted in alkali metal storage areas.

14.8.1.3.4.5 Idle metal pallets shall be permitted in alkali metal storage areas.

14.8.1.4 Molten Alkali Metal Storage. Molten alkali metal storage shall be in closed systems and in separate buildings or portions of buildings designed solely for that purpose.

14.8.2 Scrap Handling, Storage and Disposal. Alkali metals shall be handled, processed, and stored in accordance with the requirements of this chapter.

14.8.2.1 NFPA Hazard Identification Markings.

▲ **14.8.2.1.1** Alkali metal handling, processing, and storage areas having quantities greater than 2.3 kg (5 lb) shall have diamond markings as specified in NFPA 704 to make emergency responders aware of the presence of water-reactive materials within the area.

▲ **14.8.2.1.2** The diamond markings shall be at least 457.2 mm (18 in.) on each side with appropriate size numbers and symbols as specified in NFPA 704.

14.8.3 Recycling.

14.8.4 Chip Processing. (Reserved)

14.9* Fire and Explosion Protection.

▲ **14.9.1** Fire and explosion protection shall be in accordance with Chapter 8.

14.9.1.1* Alkali metal fire residues shall be stored in a designated and isolated location.

14.9.2 Housekeeping.

14.9.2.1 Dust Control. (Reserved)

14.9.2.2* Special Consideration. Alkali metals shall be kept away from sources of moisture.

14.9.3 Control of Ignition Sources.

▲ **14.9.3.1** Control of ignition sources shall be in accordance with Chapter 10.

14.9.3.2 Alkali metal fire residue containers shall be permitted to be stored outside where placed in a steel overpack drum and inspected daily.

14.9.3.2.1* Alkali metal fire residues shall be disposed of within 7 days unless the AHJ allows longer storage.

14.9.3.2.2 Alkali metal fire residues shall be protected to prevent adverse reactions and to prevent the formation of reactive or unstable compounds.

14.9.3.2.3 Alkali metal fire residues shall be disposed of in accordance with federal, state, and local regulations.

14.9.3.2.4 Prior to disposal, containers of alkali metal fire residue shall be inspected and the results recorded daily by individuals who are trained in the hazards of alkali metals and able to recognize potential problems associated with these containers.

14.9.3.2.5 Alkali metal fire residues shall be stored in metal containers that are recommended by the alkali metal manufacturer.

14.9.4* Hot Work Operations.

14.9.4.1 Hot work operations shall be in accordance with Section 10.2.

14.9.5 Control of Combustible Materials.

Δ 14.9.5.1 Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30.

14.9.5.1.1 Forge presses, heavy grinders, and other milling equipment operated by hydraulic systems of 189 L (50 gal) or greater shall use a less hazardous hydraulic fluid with a flash point greater than 93°C (200°F).

Δ 14.9.5.1.2 Dipping and coating applications of flammable or combustible liquids shall be done in accordance with NFPA 34.

Δ 14.9.5.1.3 Spray application of flammable or combustible liquids shall be done in accordance with NFPA 33.

14.9.5.2 Ordinary Combustible Storage.

14.9.5.2.1 Ordinary combustible materials such as paper, wood, cartons, and packing material shall not be stored or allowed to accumulate in processing areas unless necessary for the process and then only in designated areas.

14.9.5.2.2 Ordinary combustible materials shall not be discarded in containers used for the collection of combustible metal waste.

14.9.5.3 Removal of Combustible Metal Chips, Fines, Swarf, Paste, Powder, Dust, and Sweepings.

14.9.5.3.1 All combustible metal chips, lathe turnings, and swarf shall be collected in closed-top metal containers and removed daily, as a minimum, to a safe storage or disposal area.

14.9.5.3.2 Open storage of sponge, chips, fines, and dust that are readily ignitable shall be isolated and segregated from other combustible materials and metal scrap to prevent propagation of a fire.

14.9.6 Inspection, Maintenance, and Training. (Reserved)

14.10 Other. (Reserved)

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N Chapter 15 Legacy Metals

N 15.1* General.

N 15.1.1 Reactivity.

N 15.1.1.1 It shall be the responsibility of the facility to evaluate processes and materials for potentially dangerous reactions that could occur in the course of their operations.

N 15.1.1.2 Reactive molten metals shall be contained in closed systems that prevent their unintentional contact with air or reactive materials.

N 15.1.2* Contact with Water. Water leakage inside or into any building where the water can contact water reactive metals shall be prevented to avoid possible spontaneous heating.

N 15.1.3* Thermite Reactions. Caution shall be exercised in the mixing of fines or molten material with metal oxides [e.g., iron oxide (rust)].

N 15.1.4* Eutectic Reactions. It shall be the responsibility of the facility to research processing and materials for potentially dangerous reactions and eutectic compositions, which could occur in the course of their activities.

N 15.1.5 Dust Collection. Dust collection shall be in accordance with Chapter 11.

N 15.1.6 Ignition Sources. Electrical power and ignition sources shall be in accordance with Chapter 10.

N 15.1.7 Hot Work.

N 15.1.7.1 Hot work operations shall be in accordance with Section 10.2 and the requirements of this section.

N 15.1.7.2* All welding of legacy metals shall be carried out under an inert atmosphere, such as helium or argon, or under vacuum.

N 15.1.8 Fire Extinguishers. Portable fire extinguishers shall be in accordance with Chapter 8.

N 15.1.9 Fire Protection. Fire suppression systems shall be in accordance with Chapter 8.

N 15.2* Facility Design Requirements.

N 15.2.1 General.

N 15.2.1.1 Individuals or firms designing facilities and/or equipment for the processing of the specific combustible metal shall be briefed by individual(s) or firm(s) knowledgeable in the specific hazards associated with manufacturing, handling, processing, and storage of the specific combustible metal and this standard.

N 15.2.1.2 In addition to the requirements of this chapter, buildings shall comply with applicable provisions of locally adopted building and fire safety codes.

N 15.2.1.3 Where local, state, and national building codes require modifications, such modifications shall be permitted for conformance to these codes and where a hazard analysis is conducted to ensure modifications do not create a greater risk.

N 15.2.1.4 Installation of automatic sprinkler protection shall be in compliance with Chapter 8.

N 15.2.2 Dust Hazard Analysis (DHA).

N 15.2.2.1 Dust hazard analysis shall be in accordance with Chapter 7 and the requirements of this section.

N 15.2.2.2 A hazards analysis shall be performed to determine the material classification and the appropriate hazard classification (i.e., flammable solid, pyrophoric, or water reactive) based on the form or state of the material in determining the high hazard protection level of the structure based on maximum allowable quantity (MAQ) per control area requirements.

N 15.2.3 Building Location.

N 15.2.3.1 A hazards analysis shall be conducted to determine the minimum separation distance for individual buildings and operations within powder and primary production and melting plants.

N 15.2.3.1.1 Separate buildings shall be required where different operations such as, but not limited to, atomization, grinding, crushing, screening, blending, or packaging are performed.

N 15.2.3.1.2 More than one operation within the same building shall be permitted if the design provides equivalent protection.

N 15.2.3.1.3 Different production operations including drying rooms shall be located in separate but not adjoining buildings that are located at least 15 m (50 ft) from each other.

N 15.2.3.1.4 Two buildings less than 15 m (50 ft) apart shall be permitted if the facing wall of the exposed building is capable of resisting a blast with a gauge pressure of 13.8 kPa (2.0 psi) and is non-load-bearing, noncombustible, and without openings.

N 15.2.3.1.5 Combustible metal powder production plants shall be located on a site large enough that the buildings in which powder is manufactured are at least 90.9 m (300 ft) from public roads and from any occupied structure, such as public buildings, dwellings, and business or manufacturing establishments, other than those buildings that are a part of the combustible metal powder production plant.

N 15.2.3.1.6 Fuel supply lines shall have an emergency shutoff valve located within easy access outside of the building.

N 15.2.3.1.7 Emergency shutoff valves shall be clearly identified.

N 15.2.4 Building Construction.

N 15.2.4.1 Buildings that contain metals in a combustible form shall be constructed in accordance with the locally adopted building code.

N 15.2.4.2 Buildings housing furnaces, boring and crushing facilities, and refining operations shall be constructed of noncombustible materials.

N 15.2.4.3 Construction of other than noncombustible materials shall be permitted if equivalent protection can be demonstrated.

N 15.2.4.4 Where local, state, and national building codes require modifications, such modifications shall be permitted for conformance to these codes.

N 15.2.4.5 Walls and ceilings shall be constructed with noncombustible insulation that has been tested in accordance with

ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*.

N 15.2.4.6 Interior walls erected for the purpose of limiting fire spread shall have a minimum 1-hour fire resistance rating and shall be designed in accordance with NFPA 221.

N 15.2.4.7 All penetrations of floors, walls, ceilings, or partitions where combustible dust is present shall be dusttight, and where structural assemblies have a fire resistance rating, the seal shall maintain that rating.

N 15.2.4.8 Sealing of penetrations shall not be required when the penetrated barrier is provided for reasons other than to limit the migration of dusts or to control the spread of fire or explosion.

N 15.2.4.9 The annulus of all pipe, conduit, and ventilation penetrations shall be sealed.

N 15.2.4.10 All walls of areas where fugitive dust can be produced shall have a smooth finish and shall be sealed to leave no interior or exterior voids where dust can infiltrate and accumulate.

N 15.2.4.10.1 The requirements of 15.2.4.10 shall also apply to elevated platforms, balconies, floors, and gratings.

N 15.2.5 Floors.

N 15.2.5.1 Floors shall be of a noncombustible hard surface, nonslip material and installed with a minimum number of joints in which powder can collect.

N 15.2.5.1.1 The requirements of 15.2.5.1 shall also apply to elevated platforms, balconies, floors, and gratings.

N 15.2.5.2 Floors in reduction, boring, and crushing buildings shall be made of noncombustible materials, such as concrete, brick, or steel plate.

N 15.2.5.3 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate fire-fighting operations.

N 15.2.6 Roofs.

N 15.2.6.1 Roofs of buildings that house combustible metal dust-producing operations shall be supported on girders or structural members designed to minimize surfaces on which dust can collect.

N 15.2.6.1.1* Roof decks shall be watertight.

N 15.2.7 Surfaces.

N 15.2.7.1 The buildings shall be designed so that all internal surfaces are readily accessible to facilitate cleaning.

N 15.2.7.1.1* Interior surfaces where dust accumulations can occur shall be designed and constructed (and angle greater than the angle of repose) to facilitate cleaning and to minimize combustible dust accumulation.

N 15.2.8 Protective Openings.

N 15.2.8.1 Means of egress shall be provided in compliance with NFPA 101.

N 15.2.8.2 All doors in interior fire-rated partitions shall be listed, self-closing fire doors installed in accordance with NFPA 80.

N 15.2.9 Enclosed Passageways.

N 15.2.9.1* Where buildings or process areas are interconnected by enclosed passageways, and there is a deflagration hazard, the passageways shall be designed to prevent propagation of an explosion or fire from one unit to another in accordance with NFPA 68.

N 15.2.9.2 All enclosed passageways that can be occupied and that connect with one or more processing areas shall be provided with means of egress in accordance with NFPA 101.

N 15.2.10 Heating and Cooling of Buildings.

N 15.2.10.1 Buildings shall be permitted to be heated by indirect hot-air heating systems, by bare-pipe heating systems using steam or hot water as the heat transfer medium, or by listed electric heaters.

N 15.2.10.1.1 Indirect hot air shall be permitted if the heating unit is located in a combustible metal dust-free area adjacent to the room or area where heated air is required.

N 15.2.10.1.2 Fans or blowers used to convey the heated or cooled air shall be located in a combustible metal dust-free location.

N 15.2.10.1.3 The air supply shall be taken from outside or from a location that is free of combustible metal dust.

N 15.2.10.1.4 Make-up air for building heating or cooling shall have a dew point low enough to ensure that no free moisture can condense at any point where the air is in contact with combustible metal dust or powder.

N 15.2.10.1.5 The requirements of 15.2.10.1.1 through 15.2.10.1.4 shall not apply to areas where metal is melted.

N 15.2.11* Ventilation.

N 15.2.11.1 Where hydrogen generation occurs during the process, ventilation shall be provided for dissipation of hydrogen to the atmosphere.

N 15.2.11.2 Mechanical ventilation systems shall be designed and installed in accordance with the locally adopted building and fire code.

N 15.2.12 Explosion Mitigation/Deflagration Venting.

N 15.2.12.1* Explosion venting in accordance with NFPA 68 shall be required for all buildings or building areas where combustible metal powders or dusts are present, unless a hazard analysis has been performed that shows that explosion venting is not required.

N 15.2.12.2 In accordance with NFPA 68, deflagration vent closures shall be directed toward a personnel-restricted area, and the vent closure shall be restrained to minimize the missile hazard to personnel and equipment.

N 15.2.12.3* Relief valves shall not be vented to a dust hazard area.

N 15.2.12.4 Equipment shall be located or arranged in a manner that minimizes combustible dust accumulations on surfaces.

N 15.2.12.5 Deflagration venting shall not be required for areas where combustible metal powder is stored or moved only in covered or sealed containers.

N 15.2.13 Separation from Water.

N 15.2.13.1 Combustible metal winning, refining, and casting operations shall be protected from rain and from other possibilities of inadvertent contact with water.

N 15.2.13.1.1* Water pipes or pipes that can contain water for uses other than process or production support (e.g., sprinkler piping, domestic water pipes, roof drains, and waste pipes) are not permitted in areas containing combustible metals unless a hazards analysis is performed.

N 15.2.13.1.2 Permitted piping in areas in which a combustible metal fire may occur shall be equipped with an emergency shutoff that is identified, located outside the area, and of all-metal construction.

N 15.2.14 Drying Rooms.

N 15.2.14.1 A hazards analysis shall be performed to determine the proper type of drying used for the specific powders being handled as well as the specific parameters used for drying.

N 15.3 Primary Metal Production.

N 15.3.1 Aluminum. This standard shall not apply to the primary production of aluminum.

N 15.3.1.1 Reduction. (Reserved)**N 15.3.1.2 Refining. (Reserved)****N 15.3.1.3 Melting and Casting. (Reserved)**

N 15.3.2 Magnesium. This standard shall not apply to the primary production of magnesium.

N 15.3.2.1 Reduction. (Reserved)**N 15.3.2.2 Refining. (Reserved)****N 15.3.2.3* Melting and Casting.**

N 15.3.2.3.1 Buildings used for the melting and casting of magnesium shall be noncombustible.

N 15.3.2.3.1.1 Melt rooms shall provide access to facilitate fire control.

N 15.3.2.3.1.2* Floors shall be of noncombustible construction and shall be kept clean and free of moisture and standing water.

N 15.3.2.3.2* All solid metal shall be thoroughly dried by preheating and shall be at a temperature not less than 121°C (250°F) throughout when coming into contact with molten magnesium.

N 15.3.2.3.3 Fuel supply lines to melting pots and preheating installations shall have remote fuel shutoffs and combustion safety controls in accordance with NFPA 86 or equivalent.

N 15.3.2.3.4* Prevention of Molten Magnesium Contact with Foreign Materials.

N 15.3.2.3.4.1 Areas of furnaces that can come into contact with molten magnesium in the event of a runout shall be kept dry and free of iron oxide.

N 15.3.2.3.4.2 Crucible interiors and covers shall be maintained free of iron oxide scale, which could fall into the molten metal.

N 15.3.2.3.4.3 Molten magnesium systems shall overflow or relieve to secondary containments designed to handle

110 percent of the largest expected failure and shall be provided with the means to prevent contact with incompatible materials.

N 15.3.2.3.4.4 Melting pots and crucibles shall be inspected regularly.

N 15.3.2.3.4.5 Pots and crucibles that show evidence of possible failure or that allow molten metal to contact iron oxide, concrete, or other incompatible materials shall be repaired or discarded.

N 15.3.2.3.5 Ladles, skimmers, and sludge pans shall be thoroughly dried and preheated before contacting molten metal.

N 15.3.2.3.6 Extreme care shall be exercised in pouring magnesium castings to avoid spillage.

N 15.3.2.3.7 All molds shall be thoroughly preheated before pouring magnesium castings.

N 15.3.2.3.8 Operators in melting and casting areas shall wear flame-resistant clothing, high foundry shoes, and face protection.

N 15.3.2.3.9 Clothing worn where molten magnesium is present shall have no exposed pockets or cuffs that could trap and retain magnesium.

N 15.3.3 Niobium.

N 15.3.3.1 Reduction. (Reserved)

N 15.3.3.2 Refining. (Reserved)

N 15.3.3.3 Melting and Casting. (Reserved)

N 15.3.3.3.1* Explosion Prevention.

N 15.3.3.3.1.1* Sealed vessels shall be designed and maintained to prevent water from entering the reaction chamber.

N 15.3.3.3.1.2 Sealed vessels shall be permitted to be water cooled and shall be designed to prevent water from entering the vessel.

N 15.3.3.3.1.3* Water-cooled furnaces shall have the crucible and its water jacket located in a protective noncombustible enclosure that provides a means of isolation to protect personnel and to minimize damage to adjacent structures and equipment if an explosion occurs.

N 15.3.3.3.1.4 The fill used for furnace containment shall be designed to minimize the potential for the material to slough into the furnace cavity after an explosion.

N 15.3.3.3.2 Upper Chamber of the Furnace.

N 15.3.3.3.2.1* The upper chamber of the furnace shall be provided with a pressure-relieving device to aid in relieving pressure if water enters the furnace.

N 15.3.3.3.2.2 Means shall be provided to prevent the influx of air through the pressure-relief port.

N 15.3.3.3.2.3 Large low-pressure ports shall not be used.

N 15.3.3.3.2.4* A clearance shall be maintained at all times between the electrode and the crucible wall to minimize arcing to the crucible wall.

N 15.3.3.3.2.5* The furnace shall be equipped with a device that continuously senses pressure within the furnace.

N (A) The device shall automatically interrupt power to the melting heat source in the event of an unexpected sharp rise in pressure.

N (B) The furnace shall be equipped with the following:

- (1) Waterflow, temperature, and pressure sensors on all cooling systems
- (2) Arc voltage recorders and melting power recorders
- (3) Electrode position indicators
- (4) Furnace pressure sensors and recorders
- (5) Set point alarms on critical process systems to warn of abnormal conditions

N (C) Furnaces shall comply with NFPA 86.

N 15.3.3.3.2.6* Water-cooled crucibles shall be inspected to ensure that minimum wall thicknesses are maintained to prevent a breach of the crucible wall.

N 15.3.3.3.3* Molds.

N 15.3.3.3.3.1 Molds for niobium casting shall be made of material that is compatible with molten niobium.

N 15.3.3.3.3.2 Molds shall be dried thoroughly and shall be stored to prevent accumulation of moisture in the molds.

N 15.3.3.3.3.3 Because mold breaks are inevitable, the casting chamber shall be cooled or shall be large enough to serve as a heat sink, or both, to provide the protection necessary in the event of a spill.

N 15.3.3.3.3.4* Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside of furnace enclosures.

N 15.3.3.3.4* Residue.

N 15.3.3.3.4.1 Residue from casting furnaces shall be passivated, placed in covered metal containers that allow for hydrogen gas venting, and moved to a designated storage or disposal area.

N 15.3.3.3.4.2 The containers specified in 15.3.3.3.4.1 shall be stored so that any hydrogen gas generated vents freely.

N 15.3.3.3.5* Water Supply.

N 15.3.3.3.5.1 The water supply to crucibles shall be monitored continuously by a system that automatically interrupts power to the melting heat source on a drop in water pressure or water-flow.

N 15.3.3.3.5.2 An emergency source of cooling water shall be provided and shall be actuated automatically by flow interlock in the event of interruption of the primary cooling water.

N 15.3.3.3.5.3 Equipment construction shall mitigate the potential for ignition of the niobium powder.

N 15.3.3.3.5.4 Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside of furnace enclosures.

N 15.3.3.3.5.5 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

N 15.3.3.3.6 Personnel Safety Precautions.

N 15.3.3.3.6.1 Personal protective equipment (PPE) shall be in accordance with Section 4.6.

- N 15.3.3.3.6.2** Molten niobium shall be contained in closed systems that prevent its unintentional contact with air or reactive materials.
- N 15.3.3.3.6.3** Personnel involved in niobium melting operations with the potential for exposure to molten niobium shall wear appropriate PPE.
- N 15.3.3.3.6.4** Niobium metal shall be handled only by trained personnel who are knowledgeable of the hazards associated with niobium.
- N 15.3.3.3.7 Hot Work.** Hot work shall be in accordance with Section 10.2.
- N 15.3.4 Tantalum.**
- N 15.3.4.1 Reduction. (Reserved)**
- N 15.3.4.2 Refining. (Reserved)**
- N 15.3.4.3 Melting and Casting. (Reserved)**
- N 15.3.4.3.1* Explosion Prevention.**
- N 15.3.4.3.1.1*** Sealed vessels shall be designed and maintained to prevent water from entering the reaction chamber.
- N 15.3.4.3.1.2** Sealed vessels shall be permitted to be water cooled and shall be designed to prevent water from entering the vessel.
- N 15.3.4.3.1.3*** Water-cooled furnaces shall have the crucible and its water jacket located in a protective noncombustible enclosure that provides a means of isolation to protect personnel and to minimize damage to adjacent structures and equipment if an explosion occurs.
- N 15.3.4.3.1.4** The fill used for furnace containment shall be designed to minimize the potential for the material to slough into the furnace cavity after an explosion.
- N 15.3.4.3.2 Upper Chamber of the Furnace.**
- N 15.3.4.3.2.1*** The upper chamber of the furnace shall be provided with a pressure-relieving device to aid in relieving pressure if water enters the furnace.
- N 15.3.4.3.2.2** Means shall be provided to prevent the influx of air through the pressure-relief port.
- N 15.3.4.3.2.3** Large low-pressure ports shall not be used.
- N 15.3.4.3.2.4*** A clearance shall be maintained at all times between the electrode and the crucible wall to minimize arcing to the crucible wall.
- N 15.3.4.3.2.5*** The furnace shall be equipped with a device that continuously senses pressure within the furnace.
- N (A)** The device shall automatically interrupt power to the melting heat source in the event of an unexpected sharp rise in pressure.
- N (B)** The furnace shall be equipped with the following:
- (1) Waterflow, temperature, and pressure sensors on all cooling systems
 - (2) Arc voltage recorders and melting power recorders
 - (3) Electrode position indicators
 - (4) Furnace pressure sensors and recorders
 - (5) Set point alarms on critical process systems to warn of abnormal conditions
- N (C)** Furnaces shall comply with NFPA 86.
- N 15.3.4.3.2.6*** Water-cooled crucibles shall be inspected to ensure that minimum wall thicknesses are maintained to prevent a breach of the crucible wall.
- N 15.3.4.3.3* Molds.**
- N 15.3.4.3.3.1** Molds for tantalum casting shall be made of material that is compatible with molten tantalum.
- N 15.3.4.3.3.2** Molds shall be dried thoroughly and shall be stored to prevent accumulation of moisture in the molds.
- N 15.3.4.3.3.3** Because mold breaks are inevitable, the casting chamber shall be cooled or shall be large enough to serve as a heat sink, or both, to provide the protection necessary in the event of a spill.
- N 15.3.4.3.3.4*** Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside of furnace enclosures.
- N 15.3.4.3.4* Residue.**
- N 15.3.4.3.4.1** Residue from casting furnaces shall be passivated, placed in covered metal containers that allow for hydrogen gas venting, and moved to a designated storage or disposal area.
- N 15.3.4.3.4.2** The containers specified in 15.3.4.3.4.1 shall be stored so that any hydrogen gas generated vents freely.
- N 15.3.4.3.5* Water Supply.**
- N 15.3.4.3.5.1** The water supply to crucibles shall be monitored continuously by a system that automatically interrupts power to the melting heat source on a drop in water pressure or water-flow.
- N 15.3.4.3.5.2** An emergency source of cooling water shall be provided and shall be actuated automatically by flow interlock in the event of interruption of the primary cooling water.
- N 15.3.4.3.5.3** Equipment construction shall mitigate the potential for ignition of the tantalum powder.
- N 15.3.4.3.5.4** Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside of furnace enclosures.
- N 15.3.4.3.5.5** Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.
- N 15.3.4.3.6 Personnel Safety Precautions.**
- N 15.3.4.3.6.1** PPE shall be in accordance with Section 4.6.
- N 15.3.4.3.6.2** Molten tantalum shall be contained in closed systems that prevent its unintentional contact with air or reactive materials.
- N 15.3.4.3.6.3** Personnel involved in tantalum melting operations with the potential for exposure to molten tantalum shall wear appropriate PPE.
- N 15.3.4.3.6.4** Tantalum metal shall be handled only by trained personnel who are knowledgeable of the hazards associated with tantalum.
- N 15.3.4.3.7 Hot Work.** Hot work shall be in accordance with Section 10.2.

N 15.3.5 Titanium.**N 15.3.5.1 Reduction.**

N 15.3.5.1.1 Reactor vessels shall be air-cooled.

N 15.3.5.1.2 Sealed titanium-reduction vessels shall be permitted to be water cooled and shall be designed to prevent water from entering the reaction vessel.

N 15.3.5.1.3 All containers used to receive molten magnesium, molten titanium, or molten titanium chloride shall be cleaned and dried thoroughly before use.

N 15.3.5.1.4 Sponge discharged from dryers shall be collected in containers that have a capacity no larger than 1814 kg (4000 lb).

N 15.3.5.1.5 Combustible materials shall be minimized in the (sponge) collection area, well-ventilated and free from other materials.

N 15.3.5.1.6 Dust resulting from the crushing of titanium sponge shall be managed safely to minimize the risk of fires and explosions.

N 15.3.5.2 Refining. (Reserved)**N 15.3.5.3 Melting and Casting.****N 15.3.5.3.1 General Provisions.**

N 15.3.5.3.1.1 The water supply to crucibles shall be monitored continuously by a system that automatically interrupts power to the furnace on a drop in water pressure or water flow.

N 15.3.5.3.1.2 An emergency source of cooling water shall be provided for crucibles and shall be actuated automatically by flow interlock in the event of interruption of the primary cooling water.

N 15.3.5.3.1.3 The upper chamber of the furnace shall be provided with a pressure-relieving device to aid in safely relieving pressure if water enters the furnace.

N 15.3.5.3.1.4 Means shall be provided to prevent the influx of air through the pressure-relief port.

N 15.3.5.3.1.5 The release pressure of the rupture disc shall be at a gauge pressure of 138 kPa (20 psi) maximum.

N 15.3.5.3.1.6 Large low-pressure ports shall not be used.

N 15.3.5.3.1.7 The furnace shall be equipped with a device that continuously senses pressure within the furnace.

N 15.3.5.3.1.8 The device shall automatically interrupt power to the melting heat source in the event of an expected sharp rise in pressure.

N 15.3.5.3.1.9 The furnace shall be equipped with the following:

- (1) Water flow, temperature, and pressure sensors on all cooling systems
- (2) Furnace pressure sensors and recorders
- (3) Set point alarms on all systems to warn of abnormal conditions

N 15.3.5.3.1.10 The casting chamber shall be cooled or shall be sufficiently massive to accommodate a spill, or both, since mold breaks are inevitable.

N 15.3.5.3.1.11 Iron scale and metal spillage shall be minimized in furnaces.

N 15.3.5.3.1.12 All furnace pits and bunkers shall be evaluated as confined spaces.

N 15.3.5.3.2 Molds and Crucibles.

N 15.3.5.3.2.1 Molds (and crucibles) for titanium casting (melting) shall be made of material that is compatible with molten titanium.

N 15.3.5.3.2.2 Molds (and crucibles) shall be dried thoroughly and stored carefully to prevent accumulation of moisture in the molds.

N 15.3.5.3.2.3 All pieces of titanium metal shall be clean and dry when charged to reactors.

N 15.3.5.3.3 Vacuum Arc Remelt (VAR) and Electroslag Remelting (ESR).

N 15.3.5.3.3.1 Water-cooled furnaces shall be located in a protective concrete vault, or the crucible and its water jacket shall be isolated to protect personnel and to minimize damage if an explosion occurs.

N 15.3.5.3.3.2 A clearance shall be maintained at all times between the electrode and the crucible wall to minimize arcing to the crucible wall.

N 15.3.5.3.3.3 The use of a magnetic field to deflect the electric arc away from the crucible wall shall be considered.

N 15.3.5.3.3.4 Furnaces shall be equipped with the following equipment:

- (1) Arc voltage recorders and melting power recorders
- (2) Electrode position indicators
- (3) Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside furnace vaults

N 15.3.5.3.4 Electron Beam (EB) and Plasma Arc Melting (PAM). (Reserved)**N 15.3.5.3.5 Vacuum Induction Melting (VIM) and Skull. (Reserved)****N 15.3.6 Zirconium and Hafnium.****N 15.3.6.1 Reduction.**

N 15.3.6.1.1 Reactor vessels shall be air cooled.

N 15.3.6.1.2 Sealed zirconium or hafnium-reduction vessels shall be permitted to be water cooled and shall be designed to prevent water from entering the reaction vessel.

N 15.3.6.1.3 All containers used to receive molten magnesium, molten zirconium or hafnium, or molten zirconium or hafnium chloride shall be cleaned and dried thoroughly before use.

N 15.3.6.1.4 Sponge discharged from dryers shall be collected in containers that have a capacity no larger than 1814 kg (4000 lb).

N 15.3.6.1.5 Zirconium or hafnium storage areas shall be kept free of combustible materials, shall be well ventilated, shall be equipped with the required fire protection equipment, and shall be plainly marked with "No Smoking" signs.

N 15.3.6.1.6 Dust resulting from the crushing of zirconium or hafnium sponge shall be managed safely to minimize the risk of fires and explosions.

N 15.3.6.2 Refining. (Reserved)

N 15.3.6.3 Melting and Casting.

N 15.3.6.3.1 General Provisions.

N 15.3.6.3.1.1 The water supply to crucibles shall be monitored continuously by a system that automatically interrupts power to the furnace on a drop in water pressure or water flow.

N 15.3.6.3.1.2 An emergency source of cooling water shall be provided for crucibles and shall be actuated automatically by flow interlock in the event of interruption of the primary cooling water.

N 15.3.6.3.1.3 The upper chamber of the furnace shall be provided with a pressure-relieving device to aid in safely relieving pressure if water enters the furnace.

N 15.3.6.3.1.4 Means shall be provided to prevent the influx of air through the pressure-relief port.

N 15.3.6.3.1.5 The release pressure of the rupture disc shall be at a gauge pressure of 138 kPa (20 psi) maximum.

N 15.3.6.3.1.6 Large low-pressure ports shall not be used.

N 15.3.6.3.1.7 The furnace shall be equipped with a device that continuously senses pressure within the furnace.

N 15.3.6.3.1.8 The device shall automatically interrupt power to the melting heat source in the event of an expected sharp rise in pressure.

N 15.3.6.3.1.9 The furnace shall be equipped with the following equipment:

- (1) Water flow, temperature, and pressure sensors on all cooling systems
- (2) Furnace pressure sensors and recorders
- (3) Set point alarms on all systems to warn of abnormal conditions

N 15.3.6.3.1.10 The casting chamber shall be cooled or shall be sufficiently massive to accommodate a spill, or both, since mold breaks are inevitable.

N 15.3.6.3.1.11 Iron scale and metal spillage shall be minimized in furnaces.

N 15.3.6.3.1.12 All furnace pits and bunkers shall be evaluated as confined spaces.

N 15.3.6.3.2 Molds and Crucibles.

N 15.3.6.3.2.1 Molds (and crucibles) for zirconium or hafnium casting (melting) shall be made of material that is compatible with molten zirconium or hafnium.

N 15.3.6.3.2.2 Molds (and crucibles) shall be dried thoroughly and stored carefully to prevent accumulation of moisture in the molds.

N 15.3.6.3.2.3 All pieces of zirconium or hafnium metal shall be clean and dry when charged to reactors.

N 15.3.6.3.3 Vacuum Arc Remelt (VAR) and Electroslag Remelting (ESR).

N 15.3.6.3.3.1 Water-cooled furnaces shall be located in a protective concrete vault, or the crucible and its water-jacket shall be isolated to protect personnel and to minimize damage if an explosion occurs.

N 15.3.6.3.3.2 A clearance shall be maintained at all times between the electrode and the crucible wall to minimize arcing to the crucible wall.

N 15.3.6.3.3.3 The use of a magnetic field to deflect the electric arc away from the crucible wall shall be considered.

N 15.3.6.3.3.4 Furnaces shall be equipped with the following equipment:

- (1) Arc voltage recorders and melting power recorders
- (2) Electrode position indicators
- (3) Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside furnace vaults

N 15.3.6.3.4 Electron Beam (EB) and Plasma Arc Melting (PAM). (Reserved)

N 15.3.6.3.5 Vacuum Induced Melting (VIM) and Skull. (Reserved)

N 15.4 Powder Production.

N 15.4.1 Aluminum.

N 15.4.1.1 Handling and Conveying of Aluminum Powder.

N 15.4.1.1.1 Where aluminum powder is present, good house-keeping practices shall be maintained.

N 15.4.1.1.2 Aluminum powder shall be handled to avoid spillage and the creation of airborne dust.

N 15.4.1.1.3 Scoops, shovels, and scrapers used in the handling of aluminum powder shall be electrically conductive and shall be grounded when necessary, and hand tools shall be made of spark-resistant materials.

N 15.4.1.1.4 Each container for aluminum powders shall be conductive and covered while in storage or in transit.

N 15.4.1.1.5 When aluminum powders are being charged to or discharged from machines, the containers shall be bonded to the grounded machine.

N 15.4.1.1.6 When aluminum powder is being transferred between containers, the containers shall be bonded and at least one of the containers shall be grounded.

N 15.4.1.2 Portable Containers. In-plant transport of aluminum powders shall be done in covered conductive containers as described in 15.4.1.1.4.

N 15.4.1.3 Ductwork for Pneumatic Conveying Systems. Ductwork for pneumatic conveying systems shall be in accordance with 11.5.1.

N 15.4.1.4 Conveying Using an Inert Medium. Conveying using an inert medium shall be in accordance with 11.5.2.

N 15.4.1.5 Fan and Blower Construction and Arrangement. Fan and blower construction and arrangement shall be in accordance with 11.5.3.

N 15.4.1.6 Powder Collection. Powder collection shall be in accordance with Section 11.6.

N 15.4.2 Magnesium.

N 15.4.2.1 General Precautions.

N 15.4.2.1.1 In powder-handling or manufacturing buildings and in the operation of dust-conveying systems, every precau-

tion shall be taken to avoid the production of sparks from static electricity, electrical faults, friction, or impact (e.g., iron or steel articles on stones, on each other, or on concrete).

N 15.4.2.1.2 Water leakage within or into any building where it can contact magnesium powder shall be prevented to avoid possible spontaneous heating and hydrogen generation.

N 15.4.2.1.3 Electrical heating of any resistance element or load to a high temperature in an area containing a dust hazard shall be prohibited.

N 15.4.2.1.4* Frictional heating shall be minimized by the use of lubrication, inspection programs, and maintenance programs and by techniques recommended by the equipment manufacturer.

N 15.4.2.2 Requirements for Machinery.

N 15.4.2.2.1 All combustible magnesium dust-producing machines and conveyors shall be designed, constructed, and operated so that fugitive dust is minimized.

N 15.4.2.2.2* All machinery shall be bonded and grounded to minimize the accumulation of static electric charge.

N 15.4.2.2.2.1 The requirement of 15.4.2.2.2 shall apply to stamp mortars, mills, fans, and conveyors in all areas where dust is produced or handled.

N 15.4.2.2.2.2 Static-conductive belts shall be used on belt-driven equipment.

N 15.4.2.2.3* Only grounded and bonded bearings, properly sealed against dust, shall be used.

N 15.4.2.2.4 Internal machine clearances shall be maintained to prevent internal rubbing or jamming.

N 15.4.2.2.5 High-strength permanent magnetic separators, pneumatic separators, or screens shall be installed ahead of mills, stamps, or pulverizers wherever there is any possibility that tramp metal or other foreign objects can be introduced into the manufacturing operations.

N 15.4.2.3 Startup Operations. All the machine-processing contact areas shall be thoroughly cleaned and free from water before being charged with metal and placed into operation.

N 15.4.2.4 Charging and Discharging.

N 15.4.2.4.1 All magnesium powder containers not used for shipping into or out of the plant shall be made of metal.

N 15.4.2.4.2 Where magnesium powders are charged to or discharged from machines, the containers shall be bonded to the equipment and grounded by a suitable grounding conductor.

N 15.4.2.5 Packaging and Storage.

N 15.4.2.5.1 Magnesium powder shall be stored in steel drums or other closed conductive containers.

N 15.4.2.5.2 The containers shall be tightly sealed and stored in a dry location until ready for shipment or repacking.

N 15.4.2.6 In-Plant Conveying of Magnesium Powder.

N 15.4.2.6.1 Containers.

N 15.4.2.6.1.1* In-plant transfers of powders shall be done in covered conductive containers, as described in 15.4.2.5.1.

N 15.4.2.6.1.2 Powered industrial trucks shall be selected in accordance with NFPA 505 and be consistent with Section 10.9.

N 15.4.2.6.1.3 All wheeled containers, hand trucks, and lift trucks shall be grounded.

N 15.4.2.7 Pneumatic Conveying. Pneumatic conveying shall be in accordance with Section 11.5.

N 15.4.2.8 Ductwork for Conveying Systems. Ductwork for conveying systems shall be in accordance with 11.5.1.

N 15.4.2.9 Fan Construction and Arrangement Fan construction and arrangement shall be in accordance with 11.5.3.

N 15.4.2.10 Dust Collectors. Dust collectors shall be in accordance with Chapter 11.

N 15.4.3 Niobium.

N 15.4.3.1 Equipment shall be designed, constructed, installed, and operated to mitigate the potential for ignition of the niobium.

N 15.4.3.2* Only niobium powder for immediate use shall be present in handling areas.

N 15.4.3.2.1 Daily supplies of niobium powder shall be allowed to be stored in the production area.

N 15.4.3.2.1.1 The niobium powder shall be stored in covered containers and shall be segregated from other combustible materials.

N 15.4.3.2.1.2 The maximum capacity of the container shall be such that it can be moved by available equipment.

N 15.4.3.2.1.3 The containers shall be protected from damage.

N 15.4.3.3 Transport of dry niobium powders within manufacturing operations and storage of dry niobium powders within manufacturing areas shall be done in covered conductive containers.

N 15.4.3.4 Powered industrial trucks shall be selected in accordance with NFPA 505 and be consistent with Section 10.9.

N 15.4.3.5 To minimize the risk of fire or explosion hazard in the handling of niobium powders, the equipment and process shall be designed by persons experienced and knowledgeable in the hazards of niobium powders.

N 15.4.3.6 Drying of Niobium Powder. A hazards analysis acceptable to the authority having jurisdiction (AHJ) shall be conducted to determine appropriate methods and parameters for drying of niobium powder based on the specific materials being handled and dried.

N 15.4.3.6.1* Water-wetted powder, when air dried at atmospheric pressure, shall be at a temperature not exceeding 80°C (176°F).

N 15.4.3.6.2 Powders wetted with fluids other than water, when dried in air, shall be dried at a temperature governed by the characteristics of the fluid but not exceeding 80°C (176°F).

N 15.4.3.6.3* When drying niobium powders under controlled atmospheric conditions (e.g., vacuum or inert atmosphere) and the temperature exceeds 80°C (176°F), the niobium shall be cooled to less than 80°C (176°F) prior to exposure to air.

- N 15.4.3.6.4** Drying air that contacts material that is being processed shall not be recycled to rooms, processes, or buildings.
- N 15.4.3.6.5** Dry inert gas atmosphere shall be permitted to be recycled to the drying process if passed through a filter, a dust collector, or equivalent means of dust removal capable of removing 95 percent of the suspended particulate.
- N 15.4.3.7* Dryers.**
- N 15.4.3.7.1** Dryers shall be constructed of noncombustible materials.
- N 15.4.3.7.2** Interior surfaces of dryers shall be designed so that accumulations of material are minimized and cleaning is facilitated.
- N 15.4.3.7.3*** Products of combustion, as a result of a collector fire, shall be considered when designing wet collector installations.
- N 15.4.3.7.4** Wet collectors posing a significant fire and evacuation risk shall have their exhaust air conveyed directly to the exterior of the building.
- N 15.4.3.7.5** Explosion protection shall be provided as specified in 15.4.3.5.
- N 15.4.3.7.6*** Operating controls shall be designed, constructed, installed, and monitored so that required conditions of safety for operation of the heating system, the dryer, and the ventilation equipment are maintained.
- N 15.4.3.7.7** Heated dryers shall have operating controls configured to maintain the temperature of the drying chamber within the prescribed limits.
- N 15.4.3.7.8** Excess temperature-limit controls required in 15.4.3.7.6 shall initiate an automatic shutdown that performs at least the following functions:
- (1) Sounds an alarm at a constantly attended location to prompt emergency response
 - (2) Shuts off the fuel or heat source to the dryer
 - (3) Stops the flow of product into the dryer and stops or diverts the flow out of the dryer
 - (4) Stops all airflow into the dryer
 - (5)* Maintains purge flow of inert gas
 - (6) Maintains coolant flow, if so equipped
- N 15.4.3.8** An emergency stop shall be provided that will enable manual initiation of the automatic shutdown required by 15.4.3.7.8.
- N 15.4.3.9** Heated dryers and their auxiliary equipment shall be fitted with separate excess temperature-limit controls arranged to supervise the following:
- (1) Heated air or inert gas supply to the drying chamber
 - (2) Airstream or inert gas stream representative of the discharge of the drying chamber
- N 15.4.3.10** All automatic shutdowns required by 15.4.3.8 shall require manual reset before the dryer can be returned to operation.
- N 15.4.3.11** If the niobium powder being dried has been determined, via test requirements in Chapter 5 of this standard, to be combustible, only dryers specifically determined by their manufacturers to be safe for drying combustible materials shall be allowed to be used.
- N 15.4.3.12 Powder Production.**
- N 15.4.3.12.1*** Where niobium powder is present, good house-keeping practices shall be maintained.
- N 15.4.3.12.2** A hazards analysis acceptable to the AHJ shall be conducted to determine that powder handling practices are suitable for the specific powders being used.
- N 15.4.3.12.3** Niobium powder shall be handled to avoid spillage and the creation of airborne dust.
- N 15.4.3.12.4*** Scoops, shovels, and scrapers used in the handling of dry niobium powder shall be electrically conductive and shall be bonded or grounded.
- N 15.4.3.12.5** Hand tools used in handling dry niobium powder shall be made of spark-resistant materials.
- N 15.4.3.12.6** Care shall be exercised to avoid the presence of an isolated conductor in the vicinity of niobium powder being handled.
- N 15.4.3.12.7*** The use of humidifiers in facilities where dry niobium powder is handled shall be considered.
- N 15.4.3.12.8** Sintering furnaces that handle niobium parts that are fabricated from powder shall be installed and operated in accordance with NFPA 86.
- N 15.4.3.12.9** Niobium powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.
- N 15.4.3.12.10** Furnaces shall be operated with inert atmospheres, such as helium or argon, or under vacuum.
- N 15.4.3.13 Electrical Installations. (Reserved)**
- N 15.4.3.14 Explosion Prevention and Protection.**
- N 15.4.3.14.1* Explosion Risk Evaluation and Explosion Suppression Design.** A documented risk evaluation acceptable to the AHJ shall be conducted to determine the level of explosion protection to be provided for the process. The risk valuation shall take into account the specific nature and properties of the niobium being handled.
- N 15.4.3.14.2** Where explosion protection is required per 15.4.3.14.1, one or more of the following methods shall be used:
- (1) Equipment designed to contain the anticipated explosion pressure
 - (2)* Correctly designed explosion venting
 - (3)* Explosion suppression system meeting the requirements of NFPA 69
 - (4) Inert gas used to reduce the oxygen content within the equipment to below the level prescribed by NFPA 69
 - (5)* Inert gas used to reduce the oxygen content within the equipment to below 50 percent of the limiting oxygen concentration (LOC) for the specific form of the material being processed
 - (6) Oxidant concentration reduction in accordance with NFPA 69
- N 15.4.3.14.3** If the method specified in 15.4.3.14.2(5) is used, test data for the specific dust and dilution combinations shall be provided and shall be acceptable to the AHJ.

- N 15.4.3.14.4** Recirculating comfort air shall be permitted to be returned to the work area where tests conducted by an approved testing organization prove that the collector's efficiency is great enough to provide both personnel and property safety in the particular installation.
- N 15.4.3.14.5** With regard to particulate matter in the cleaned air and accumulations of particulate matter and hydrogen in the work area, systems shall be periodically inspected and maintained to ensure correct operation.
- N 15.4.3.15* Inerting.** A supply of argon or helium as an inerting agent shall be provided on site at all times for blanketing and purging equipment.
- N 15.4.3.16 Personnel Safety Precautions.**
- N 15.4.3.16.1** PPE shall be in accordance with Section 4.6.
- N 15.4.3.16.2*** Personnel handling niobium powder shall wear static-dissipative footwear and flame-resistant clothing that are designed to minimize the accumulation of niobium powder. Static-dissipative footwear in conjunction with static dissipative flooring and flame-resistant clothing shall be used unless a hazards analysis shows that the footwear in conjunction with static-dissipative flooring and flame-resistant clothing is not required.
- N 15.4.3.16.3** Personnel handling niobium powder who wear gloves shall wear gloves made from conductive materials, unless other chemicals or hazardous materials in use require alternative materials of construction to provide protection.
- N 15.4.3.16.4** Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in case of primary system failure.
- N 15.4.3.16.5*** Niobium powder shall be handled only by trained personnel who are knowledgeable of the hazards associated with niobium powder.
- N 15.4.3.16.6** Access to niobium powder-handling areas by unauthorized personnel shall not be permitted.
- N 15.4.4 Tantalum.**
- N 15.4.4.1 Drying and Storage of Tantalum Powder.**
- N 15.4.4.1.1*** Water-wetted powder, when air-dried at atmospheric pressure, shall be at a temperature not exceeding 80°C (176°F).
- N 15.4.4.1.2** Powders wetted with fluids other than water, when dried in air, shall be dried at a temperature governed by the characteristics of the fluid but not exceeding 80°C (176°F).
- N 15.4.4.1.3** When tantalum powders are dried under controlled atmospheric conditions (e.g., vacuum or inert atmosphere) and the temperature exceeds 80°C (176°F), the tantalum shall be cooled to less than 80°C (176°F) prior to exposure to air.
- N 15.4.4.1.4* Dryers.**
- N 15.4.4.1.4.1** Drying air that contacts material that is being processed shall not be recycled to rooms, processes, or buildings.
- N 15.4.4.1.4.2** Dry inert gas atmosphere shall be permitted to be recycled to the drying process if passed through a filter, dust collector, or equivalent means of dust removal capable of removing 95 percent of the suspended particulate.
- N 15.4.4.1.4.3** Dryers shall be constructed of noncombustible materials.
- N 15.4.4.1.4.4** Interior surfaces of dryers shall be designed so that accumulations of material are minimized and cleaning is facilitated.
- N 15.4.4.1.4.5** Outward-opening access doors or openings shall be provided in all parts of the dryer and connecting conveyors to allow inspection, cleaning, maintenance, and the effective use of extinguishing agents.
- N 15.4.4.1.4.6** Explosion protection shall be provided as specified in 15.4.4.2.9.
- N 15.4.4.1.4.7** Operating controls shall be designed, constructed, installed, and monitored so that required conditions of safety for operation of the heating system, the dryer, and the ventilation equipment are maintained.
- N 15.4.4.1.4.8*** Heated dryers shall have operating controls configured to maintain the temperature of the drying chamber within the prescribed limits.
- N 15.4.4.1.4.9** Heated dryers and their auxiliary equipment shall be equipped with separate excess temperature-limit controls arranged to supervise the following:
- (1) Heated air or inert gas supply to the drying chamber
 - (2) Airstream or inert gas stream representative of the discharge of the drying chamber
- N 15.4.4.1.4.10*** Excess temperature-limit controls required in 15.4.4.1.4.9 shall initiate an automatic shutdown that performs at least the following functions:
- (1) Sounds an alarm at a constantly attended location to prompt emergency response
 - (2) Shuts off the fuel or heat source to the dryer
 - (3) Stops the flow of product into the dryer and stops or diverts the flow out of the dryer
 - (4) Stops all airflow into the dryer
 - (5) Maintains purge flow of inert gas
 - (6) Maintains coolant flow, if so equipped
- N 15.4.4.1.4.11** An emergency stop shall be provided that will enable manual initiation of the automatic shutdown required by 15.4.4.1.4.10.
- N 15.4.4.1.4.12** All automatic shutdowns required by 15.4.4.1.4.10 shall require manual reset before the dryer can be returned to operation.
- N 15.4.4.2 Tantalum Powder Handling (for Primary Producers).**
- N 15.4.4.2.1** Equipment shall be constructed to mitigate the potential for ignition of tantalum.
- N 15.4.4.2.2*** Only tantalum powder for immediate use shall be present in handling areas.
- N 15.4.4.2.2.1** Tantalum powder-handling or tantalum powder-processing areas shall not be used for primary storage of tantalum.
- N 15.4.4.2.2.2** Primary storage of ordinary combustible materials and flammable and combustible liquids shall be prohibited in tantalum-processing areas.
- N 15.4.4.2.3** Transport of dry tantalum powders within manufacturing operations and storage of dry tantalum powders within

manufacturing areas shall be done in covered conductive containers.

N 15.4.4.2.4 Where tantalum powder is present, good house-keeping practices shall be maintained.

N 15.4.4.2.5 Tantalum powder shall be handled to avoid spillage and the creation of airborne dust.

N 15.4.4.2.6 Scoops, shovels, and scrapers used in the handling of dry tantalum powder shall be electrically conductive and shall be bonded and grounded.

N 15.4.4.2.7 Hand tools used in handling dry tantalum powder shall be made of spark-resistant materials.

N 15.4.4.2.8* Sintering furnaces that handle tantalum parts that are fabricated from powder shall be installed and operated in accordance with NFPA 86.

N 15.4.4.2.8.1 Tantalum powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

N 15.4.4.2.8.2 Furnaces shall be operated with inert atmospheres, such as helium or argon, or under vacuum.

N 15.4.4.2.9 Explosion Prevention and Protection.

N 15.4.4.2.9.1* A documented risk evaluation acceptable to the AHJ shall be conducted to determine the level of explosion protection to be provided for the process.

N 15.4.4.2.9.2 Where explosion protection is required per 15.4.4.2.9.1, one or more of the following methods shall be used:

- (1) Equipment designed to contain the anticipated explosion pressure
- (2)* Appropriately designed explosion venting
- (3) Explosion suppression system meeting the requirements of NFPA 69
- (4) Inert gas used to reduce the oxygen content within the equipment to below the level prescribed by NFPA 69
- (5)* Dilution with a noncombustible dust to render the mixture noncombustible
- (6) Oxidant concentration reduction in accordance with NFPA 69

N 15.4.4.2.9.3 If the method specified in 15.4.4.2.9.2(5) is used, test data for specific dust and dilution combinations shall be provided and shall be acceptable to the AHJ.

N 15.4.4.2.9.4 Recirculating comfort air shall be permitted to be returned to the work area where tests conducted by an approved testing organization prove the collector's efficiency is great enough to provide both personnel and property safety in the particular installation, with regard to particulate matter in the cleaned air and accumulations of particulate matter and hydrogen in the work area. Systems shall be periodically inspected and maintained to ensure proper operation.

N 15.4.4.2.10* Inerting. A supply of argon or helium, as an inerting agent, shall be provided on-site at all times for blanketing and purging equipment.

N 15.4.4.2.11 Personnel Safety Precautions.

N 15.4.4.2.11.1 PPE shall be in accordance with Section 4.6.

N 15.4.4.2.11.2* Personnel handling tantalum powder shall wear static-dissipative footwear and flame-resistant clothing that are designed to minimize the accumulation of tantalum powder.

N 15.4.4.2.11.3 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

N 15.4.4.2.11.4 Tantalum powder shall be handled only by trained personnel who are knowledgeable of the hazards associated with tantalum powder.

N 15.4.4.2.11.5* Access to tantalum powder-handling areas by unauthorized personnel shall not be permitted.

N 15.4.5 Titanium.

N 15.4.5.1 Drying and Storage.

N 15.4.5.1.1 Wetted powder shall be dried at a temperature not exceeding 110°C (230°F).

N 15.4.5.1.2 Drying rooms shall be of Type I construction, as defined by NFPA 220.

N 15.4.5.1.3 Drying rooms shall be segregated as far as possible from other operations and at no time less than 15.2 m (50 ft).

N 15.4.5.1.4 An analysis shall be performed to determine whether drying rooms require deflagration venting.

N 15.4.5.1.5 Titanium powder shall be stored in sealed containers in well-ventilated areas.

N 15.4.5.1.6 The containers shall be kept free of combustibles.

N 15.4.5.1.7 The containers shall be protected from damage.

N 15.4.5.2 Titanium Powder Handling.

N 15.4.5.2.1 Special care shall be taken to prevent spills or dispersions that produce dust clouds.

N 15.4.5.2.2 Powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

N 15.4.5.2.3 Hot zones of furnaces that handle titanium in any form shall be provided with inert atmospheres or vacuum.

N 15.4.5.2.4 The furnaces shall be designed in accordance with NFPA 86, and shall be of spark proof construction and good engineering practice.

N 15.4.5.2.5 To minimize the risk of fire or explosion hazards in the handling of dry titanium powder, the equipment and processes shall be designed by persons knowledgeable in the hazards of titanium powder.

N 15.4.5.2.6 Only nonsparking tools and utensils shall be used in handling titanium powder.

N 15.4.6 Zirconium and Hafnium.

N 15.4.6.1 Drying and Storage.

N 15.4.6.1.1 Wetted powder shall be dried at a temperature not exceeding 110°C (230°F).

N 15.4.6.1.2 Drying rooms shall be of Type I construction, as defined by NFPA 220.

N 15.4.6.1.3 Drying rooms shall be segregated as far as possible from other operations and at no time less than 15.2 m (50 ft).

N 15.4.6.1.4 An analysis shall be performed to determine whether drying rooms require deflagration venting.

N 15.4.6.1.5 Zirconium or hafnium powder shall be stored in sealed containers in well-ventilated areas.

N 15.4.6.1.6 The containers shall be kept free of combustibles.

N 15.4.6.1.7 The containers shall be protected from damage.

N 15.4.6.2 Zirconium or Hafnium Powder Handling.

N 15.4.6.2.1 Special care shall be taken to prevent spills or dispersions that produce dust clouds.

N 15.4.6.2.2 Powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

N 15.4.6.2.3 Hot zones of furnaces that handle zirconium or hafnium in any form shall be provided with inert atmospheres or vacuum.

N 15.4.6.2.4 The furnaces shall be designed in accordance with NFPA 86 and shall be of spark proof construction and good engineering practice.

N 15.4.6.2.5 To minimize the risk of fire or explosion hazards in the handling of dry zirconium or hafnium powder, the equipment and processes shall be designed by persons knowledgeable in the hazards of zirconium or hafnium powder.

N 15.4.6.2.6 Only nonsparking tools and utensils shall be used in handling zirconium or hafnium powder.

N 15.5 End Users of Powder.

N 15.5.1 Aluminum.

N 15.5.1.1 Aluminum Powder Handling and Use. The provisions of 15.5.1 shall apply to operations including, but not limited to, the use of aluminum powder in the production of paste, flake powders, powdered metallurgy component manufacturing, fireworks and pyrotechnics, propellants, plasma spray coating, chemical processing, and refractories.

N 15.5.1.2 Storage. Dry aluminum powder and aluminum paste shall be stored in accordance with the provisions of 15.8.1.

N 15.5.1.3* Handling. The requirements of 15.5.1 shall apply to both regular and “nondusting” grades of aluminum powder, as well as to aluminum paste.

N 15.5.1.4 Where aluminum powder or paste is used or handled, good housekeeping practices shall be maintained in accordance with Chapter 9.

N 15.5.1.5 Scoops, shovels, and scrapers used in the handling of aluminum powder and paste shall be electrically conductive and shall be grounded when necessary, and hand tools shall be made of spark-resistant materials.

N 15.5.2 Magnesium. (Reserved)

N 15.5.3 Niobium.

N 15.5.3.1 Equipment shall be constructed to mitigate the potential for ignition of niobium powder.

N 15.5.3.2 A hazards analysis shall be performed for areas where niobium powder is present to determine risk factors and applicable controls.

N 15.5.3.3 Where the hazards analysis shows that controls are required to manage the risk of static generation, and static dissipative flooring or static-dissipative floor mats are required, personnel shall wear static-dissipative footwear or equivalent grounding devices.

N 15.5.3.4* Where static-dissipative flooring or static-dissipative floor mats are required, personnel shall wear flame-resistant clothing designed to minimize the accumulation of niobium powder.

N 15.5.3.5* Spark-resistant tools shall be used.

N 15.5.3.6 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

N 15.5.3.7* Niobium Powder Storage.

N 15.5.3.7.1 Niobium powder-handling areas or niobium powder-processing areas shall not be used for primary storage of niobium.

N 15.5.3.7.1.1 Primary storage of ordinary combustible materials and flammable and combustible liquids shall be prohibited in niobium-processing areas.

N 15.5.3.7.2 Stacked Storage.

N 15.5.3.7.2.1 Where niobium powder is stored in sealed containers, stacked storage shall be arranged to ensure stability.

N 15.5.3.7.2.2 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate fire-fighting operations.

N 15.5.3.7.3 Dry Niobium Powder Handling.

N 15.5.3.7.3.1 Precautions shall be taken to prevent spills or dispersions that produce niobium dust clouds.

N 15.5.3.7.3.2 Sintering furnaces that handle compacted niobium powder shall be installed and operated in accordance with NFPA 86.

N (A) Niobium powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

N (B) Furnaces shall be operated with inert atmospheres of argon or helium or under vacuum.

N 15.5.3.7.4 Wet Niobium Powder Handling. Water-wetted powder, when air dried at atmospheric pressure, shall be at a temperature not exceeding 80°C (176°F).

N 15.5.3.7.4.1 Powders wetted with fluids other than water, when dried in air, shall be dried at a temperature governed by the characteristics of the fluid but not exceeding 80°C (176°F).

N 15.5.3.7.4.2 When drying niobium powders under controlled atmospheric conditions (for example, vacuum or inert atmosphere) and the temperature exceeds 80°C (176°F), the niobium shall be cooled to less than 80°C (176°F) prior to exposure to air.

N 15.5.3.7.5 Heat Treatment and Passivation.

N 15.5.3.7.5.1 General.

N (A) Equipment shall be designed, constructed, installed, and operated to mitigate the potential for accumulation and ignition of niobium.

N (B) Fuel supply lines to gas-fired furnaces or other gas-fired equipment shall be installed and maintained in accordance with NFPA 54.

N (C) Furnaces shall comply with NFPA 86.

N 15.5.3.7.6 Personnel Safety Precautions.

N 15.5.3.7.6.1 Niobium metal shall be handled only by trained personnel who are knowledgeable of the hazards associated with niobium.

N 15.5.3.7.6.2 Access to niobium-handling areas by unauthorized personnel shall not be permitted.

N 15.5.3.7.6.3 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

N 15.5.3.7.7 Niobium Powder Heat Treatment and Sintering.

N 15.5.3.7.7.1 After niobium powder furnacing, the niobium powder shall be passivated prior to exposure to air atmosphere.

N 15.5.3.7.7.2 Furnaced niobium powder shall be cooled to 50°C (122°F) or less prior to starting passivation.

N 15.5.3.7.7.3 Furnaced niobium powder shall be monitored during passivation to ensure that uncontrolled oxidation, resulting in unacceptable temperature increase of the niobium, does not occur.

N 15.5.3.7.8* Heat Treatment and Sintering of Niobium Compacts.

N 15.5.3.7.8.1 Sintered niobium compacts shall be cooled to 50°C (122°F) or less prior to removal from the furnace.

N 15.5.3.7.8.2 Sintered niobium compacts shall be isolated from other combustible materials until their temperature has stabilized below 50°C (122°F).

N 15.5.3.7.9 Safety Precautions.

N 15.5.3.7.9.1 If the furnace primary cooling source fails, an alternative system shall provide cooling for the furnace for any required cool down time period.

N 15.5.3.7.9.2 The alternative cooling system specified in 15.5.3.7.9.1 shall be activated automatically on failure of the main cooling source and shall be interlocked to prevent operation of the furnace.

N 15.5.4 Tantalum.

N 15.5.4.1 General.

N 15.5.4.1.1* Equipment shall be constructed to mitigate the potential for ignition of tantalum powder.

N 15.5.4.1.2 A hazards analysis shall be performed for areas where tantalum powder is present to determine risk factors and appropriate controls.

N 15.5.4.1.3* Where the hazards analysis shows that controls are required to manage the risk of static generation, and static dissipative flooring or static-dissipative floor mats are required, personnel shall wear static-dissipative footwear or equivalent grounding devices.

N 15.5.4.1.4* Where static-dissipative flooring or static-dissipative floor mats are required, personnel shall wear flame-resistant clothing designed to minimize the accumulation of tantalum powder.

N 15.5.4.1.5* Spark-resistant tools shall be used.

N 15.5.4.1.6 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

N 15.5.4.2 Tantalum Powder Storage.

N 15.5.4.2.1 Daily supplies of tantalum powder shall be allowed to be stored in the production area.

N 15.5.4.2.1.1 The tantalum powder shall be stored in covered containers and shall be segregated from other combustible materials.

N 15.5.4.2.1.2 The maximum capacity of the container shall be such that it can be moved by available equipment.

N 15.5.4.2.1.3 The containers shall be protected from damage.

N 15.5.4.2.2 Stacked Storage.

N 15.5.4.2.2.1 When storing tantalum powder in sealed containers, stacked storage shall be arranged to ensure stability.

N 15.5.4.2.2.2 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate fire-fighting operations.

N 15.5.4.3 Dry Tantalum Powder Handling.

N 15.5.4.3.1* Precautions shall be taken to prevent spills or dispersions that produce tantalum dust clouds.

N 15.5.4.3.2 Sintering furnaces that handle compacted tantalum powder shall be installed and operated in accordance with NFPA 86.

N 15.5.4.3.2.1 Tantalum powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

N 15.5.4.3.2.2 Furnaces shall be operated with inert atmospheres of argon or helium or under vacuum.

N 15.5.4.4 Wet Tantalum Powder Handling by End Users.

N 15.5.4.4.1* Water-wetted powder, when air-dried at atmospheric pressure, shall be at a temperature not exceeding 80°C (176°F).

N 15.5.4.4.2 Powders wetted with fluids other than water, when dried in air, shall be dried at a temperature governed by the characteristics of the fluid but not exceeding 80°C (176°F).

N 15.5.4.4.3 When tantalum powders are dried under controlled atmospheric conditions (e.g., vacuum or inert atmosphere) and the temperature exceeds 80°C (176°F), the tantalum shall be cooled to less than 80°C (176°F) prior to exposure to air.

N 15.5.4.5 Heat Treatment and Passivation.

N 15.5.4.5.1 General.

N 15.5.4.5.1.1 Equipment shall be designed, constructed, and installed to mitigate the potential for ignition and accumulation of tantalum.

N 15.5.4.5.1.2 Fuel supply lines to gas-fired furnaces or other gas fired equipment shall be installed and maintained in accordance with NFPA 54.

N 15.5.4.5.1.3 Furnaces shall comply with NFPA 86.

N 15.5.4.6* Personnel Safety Precautions.

N 15.5.4.6.1 Tantalum metal shall be handled only by trained personnel who are knowledgeable of the hazards associated with tantalum.

N 15.5.4.6.2 Access to tantalum-handling areas by unauthorized personnel shall not be permitted.

N 15.5.4.6.3 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

N 15.5.4.7 Tantalum Powder Heat Treatment and Sintering.

N 15.5.4.7.1 After tantalum powder furnacing, the tantalum powder shall be passivated prior to exposure to air atmosphere.

N 15.5.4.7.2 Furnaced tantalum powder shall be cooled to 50°C (122°F) or less prior to starting passivation.

N 15.5.4.8* Heat Treatment and Sintering of Tantalum Compacts.

N 15.5.4.8.1* Sintered tantalum compacts shall be cooled to 50°C (122°F) or less prior to removal from the furnace.

N 15.5.4.8.2 Sintered tantalum compacts shall be isolated from other combustible materials until their temperature has stabilized below 50°C (122°F).

N 15.5.4.9 Safety Precautions.

N 15.5.4.9.1 If the furnace primary cooling source fails, an alternative system shall provide cooling for the furnace for any required cool down time period.

N 15.5.4.9.2 The alternative cooling system specified in 15.5.4.9.1 shall be activated automatically on failure of the main cooling source and shall be interlocked to prevent operation of the furnace.

N 15.5.5 Titanium. (Reserved)

N 15.5.6 Zirconium and Hafnium. (Reserved)

N 15.6 Processing and Handling.

N 15.6.1 Machining and Operations.

N 15.6.1.1* Where metals are processed with a flammable or combustible liquid, the requirements of NFPA 30 shall also be followed for the flammable or combustible liquids.

N 15.6.2 Requirements for Machinery.

N 15.6.2.1 All combustible metal dust-producing machines and conveyors shall be designed, constructed, and operated so that fugitive dust is minimized.

N 15.6.2.2* All machinery shall be bonded and grounded to minimize accumulation of static electric charge.

N 15.6.2.3 Before being placed into operation, all areas of processing machinery that will be in contact with combustible metal shall be free of the following:

- (1) Foreign objects and materials
- (2) Water, where combustible metal is reactive with water

N 15.6.2.4* Wet Milling of Metal Powder. The requirements of 15.6.2.4.1 through 15.6.2.4.5 shall not apply to machining and rolling operations.

N 15.6.2.4.1* Where metal is added to a mill in the presence of a liquid that is chemically inert with respect to the metal, the milling shall be done in air in a vented mill or in an inerting atmosphere containing sufficient oxygen to oxidize any newly exposed surfaces as they are formed.

N 15.6.2.4.2* Where metal is slurried in tanks or processed in blenders or other similar equipment in the presence of a liquid that is chemically inert with respect to the metal, the operation shall be carried out in air or in an inerting atmosphere containing sufficient oxygen to oxidize any newly exposed surfaces as they are formed.

N 15.6.2.4.3 The dew point of the atmospheres in 15.6.2.4.1 and 15.6.2.4.2 shall be maintained below the point where condensation occurs.

N 15.6.2.4.4* Ventilation in accordance with NFPA 30 shall be maintained in areas where flammable or combustible solvents are handled, particularly in areas where combustible metal dusts or powders are present.

N 15.6.2.4.5 Solvent or slurry pumps shall be installed with controls that ensure that a flow exists and that the pumps run with safe operating temperatures.

N 15.6.3 Plasma Spray Operations.

N 15.6.3.1 For plasma spray operations, media collectors, if used, shall be located at a distance from the point of collection to eliminate the possibility of hot metal particles igniting the filter media in the collector.

N 15.6.3.2 Metal overspray temperatures at the dust collector shall be compatible with the limiting temperature of the filter media element.

N 15.6.4 Transfer Operations.

N 15.6.4.1* Operations involving the transfer of combustible metal dusts or powders from one container to another shall be designed and operated to protect personnel, equipment, and buildings from the fire or dust explosion hazard produced by airborne suspensions of combustible metal dusts or powders.

N 15.6.5 Processing Recycled Material. The requirements of Chapter 17 shall apply to processes handling recycled metal that is in a combustible form.

N 15.7* Machining, Fabrication, Finishing and Media Blasting.

N 15.7.1 General Precautions.

N 15.7.1.1 Any equipment used for the machining, fabrication, or finishing of a single metal shall be dedicated to that metal only and marked with a placard that reads as follows:

**WARNING: (INSERT SPECIFIC METAL NAME) METAL
ONLY — FIRE OR EXPLOSION CAN RESULT WITH
OTHER METALS.**

N 15.7.1.2 Equipment producing metal in a combustible form shall be permitted to be used for other materials only when the system is thoroughly cleaned of all incompatible materials prior to and after its use.

N 15.7.1.3 It shall be permitted to use equipment for the machining, fabrication, or finishing for multiple metals without placarding where the risk of a thermite reaction (*see 15.1.3*) has been shown to be inapplicable for those metals through the performance of a hazard analysis.

N 15.7.2* Machining and Sawing Operations.

N 15.7.2.1* Equipment shall be designed, constructed, installed, and operated to mitigate the potential for accumulation and ignition of metals.

N 15.7.2.1.1 The collected solids shall be moved to a designated storage or disposal area.

N 15.7.2.1.2 Crushed lathe turnings, raw turnings, and chips shall be collected in covered metal containers and removed daily to a designated storage or disposal area.

N 15.7.2.1.3 Where fully dense forms of niobium metal are conditioned via grinding or sanding operations, consideration shall be given to ensure that the residual dusts produced are handled in a safe fashion.

N 15.7.2.1.4 A hazards analysis shall be conducted to ensure that these operations do not contribute to fugitive dust accumulation.

N 15.7.2.1.5 If dust collection is used for grinding and sanding applications, take-up hoods shall be designed to minimize the accumulation of dust.

N 15.7.2.2 Cutting Tools.

N 15.7.2.2.1* Cutting tools shall be of proper design and shall be kept sharp for satisfactory work with the metal.

N 15.7.2.2.2 Cutting tools shall not be permitted to ride on the metal without cutting, because frictional heat can ignite any fine metal that is scraped off.

N 15.7.2.2.3 Because frictional heat can ignite any fine metal that is scraped off, the tool shall be backed off as soon as the cut is finished.

N 15.7.2.2.4 Cutting tools shall be kept sharp and ground with sufficient rake clearance to minimize rubbing on the end and sides of the tool.

N 15.7.2.3 All machines shall be provided with a pan or tray to catch chips or turnings.

N 15.7.2.3.1 The pan construction shall be sufficient to minimize the potential for burn-through.

N 15.7.2.3.2 In the case of fire in the chips, turnings, or compacted metal powder, the pan or tray shall not be disturbed or moved, except by an individual knowledgeable in the fire aspects of the metal, until the fire has been extinguished and the material has cooled to ambient temperature.

N 15.7.2.3.3* The pan or tray shall be installed so that it is accessible for chip, turning, or compacted metal powder removal and for application of an extinguishing agent to control a fire.

N 15.7.2.4 Consideration should be given to the potential ignition sources associated with the operation of cleaning and processing equipment during the cleaning operation.

N 15.7.2.4.1 During metal-machining operations, chips shall be removed from the point of generation by continuous or batch removal.

N 15.7.2.4.2 Periodic cleaning of metal chips from buildings and machinery shall be carried out as frequently as conditions warrant.

N 15.7.2.4.3* All metal chips, oily crushed lathe turnings, raw turnings, and swarf shall be collected in closed-top containers dedicated to the specific metal only and removed daily, at a minimum, to a safe storage or disposal area.

N 15.7.2.4.4 It shall be permitted to collect multiple metals in the same container where the risk of a thermite reaction (*see 15.1.3*) has been shown to be inapplicable for those metals through the performance of a hazard analysis.

N 15.7.2.4.5 Floor sweepings and other waste materials are prohibited from being placed in containers used for the collection of metals, metals scrap, and metal waste.

N 15.7.2.5 Coolant.

N 15.7.2.5.1 Noncombustible coolants shall be used for wet grinding, cutting, and sawing operations.

N 15.7.2.5.2* Flammable or combustible liquids shall be handled in accordance with NFPA 30.

N 15.7.2.5.3* Coolants with a flash point greater than 200°F shall be permitted for wet grinding, cutting, or sawing operations where a hazard analysis has shown it to be acceptable.

N 15.7.2.5.4 The coolant shall be filtered on a continuous basis, and the collected solids shall not be allowed to accumulate in quantities greater than 19 L (5 gal) and shall be removed to a safe storage or disposal area.

N 15.7.2.5.5* Forge presses, heavy grinders, and other milling equipment operated by hydraulic systems shall use a fluid with a flash point greater than 93°C (200°F).

N 15.7.3* Machining Magnesium.

N 15.7.3.1 The specific requirements of 15.7.3 apply only to magnesium operations.

N 15.7.3.2 Periodic cleaning of magnesium chips from buildings and machinery shall be carried out as frequently as conditions warrant.

N 15.7.3.3 Chips shall be removed to a safe storage or disposal area.

N 15.7.3.4 Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30.

N 15.7.3.5 Smoking shall not be permitted in areas where ignitable magnesium chips are present.

N 15.7.3.5.1 Areas in which ignitable magnesium chips are present shall be posted with "No Smoking" signs.

N 15.7.3.5.2 Where smoking is prohibited throughout the entire plant, the use of signage shall be at the discretion of the facility management.

N 15.7.3.6 Dust Collection. Dust collection shall be in accordance with Chapter 11.

N 15.7.3.7* Machining.

N 15.7.3.7.1 Cutting tools shall not be permitted to ride on the metal without cutting, because frictional heat can ignite any fine metal that is scraped off.

N 15.7.3.7.1.1 Because frictional heat can ignite any fine metal that is scraped off, the tool shall be backed off as soon as the cut is finished.

- N 15.7.3.7.1.2** Cutting tools shall be kept sharp and ground with sufficient rake clearance to minimize rubbing on the end and sides of the tool.
- N 15.7.3.7.2*** When drilling deep holes (depth greater than five times the drill diameter) in magnesium, high-helix drills (45 degrees) shall be used to prevent packing of the chips produced.
- N 15.7.3.7.3** Relief shall be maintained on tools used in grooving and parting operations, because the tool tends to rub the sides of the groove as it cuts.
- N 15.7.3.7.3.1** Side relief shall be 5 degrees.
- N 15.7.3.7.3.2** End relief shall be from 10 degrees to 20 degrees.
- N 15.7.3.7.4** If lubrication is needed, as in tapping or extremely fine grooving, a high-flash point lubricant shall be used.
- N 15.7.3.7.4.1** Water, water-soluble oils, and oils containing more than 0.2 percent fatty acids shall not be used, because they can generate flammable hydrogen gas.
- N 15.7.3.7.4.2** Special formulated coolant fluids (water-oil emulsions) that specifically inhibit the formation of hydrogen gas shall be permitted.
- N 15.7.3.7.5** Where compressed air is used as a coolant, special precautions shall be taken to keep the air dry.
- N 15.7.3.7.6** All machines shall be provided with a pan or tray to catch chips or turnings.
- N 15.7.3.7.6.1** The pan or tray shall be installed such that it can be readily withdrawn from the machine in case of fire.
- N 15.7.3.7.6.2** The pan shall be readily accessible for chip removal and for application of an extinguishing agent to control a fire.
- N 15.7.3.7.6.3** During magnesium-machining operations, chips shall be removed from the point of generation by continuous or batch removal.
- N (A)** Accumulation of chips at the point of generation shall not exceed 1.4 kg (3 lb) dry weight.
- N (B)** All chips shall be stored in covered noncombustible containers and removed to a storage area in accordance with 15.8.2.
- N 15.7.3.7.6.4** In case of a fire in the chips, the pan or tray shall be immediately withdrawn from the machine but shall not be picked up or carried away until the fire has been extinguished.
- N 15.7.3.8 Cleaning.**
- N 15.7.3.8.1** Systematic cleaning of the entire grinding area, including roof members, pipes, conduits, and so on, shall be carried out daily or as often as conditions warrant.
- N 15.7.3.8.2** Cleaning shall be done using soft brushes and conductive, nonsparking scoops and containers.
- N 15.7.3.8.3*** Vacuum cleaners shall not be used unless they are specifically listed for use with magnesium powder or dusts.
- N 15.7.3.8.4** Machinery and equipment using grinding wheels shall not be used for processing other metals until the entire grinder and the dust collection system are thoroughly cleaned, and the grinding wheel or belt shall be replaced prior to work on other metals.
- N 15.7.3.9 Drawing, Spinning, and Stamping.**
- N 15.7.3.9.1** Reliable means to prevent overheating shall be provided where magnesium is heated for drawing or spinning.
- N 15.7.3.9.2** Clippings and trimmings shall be collected at frequent intervals and placed in clean, dry steel or other noncombustible containers.
- N 15.7.3.9.3** Fine particles shall be handled according to the requirements of Chapters 9 and 11.
- N 15.7.3.10* Heat Treating.**
- N 15.7.3.10.1** A standard procedure for checking the uniformity of temperatures at various points within heat-treating furnaces shall be established.
- N 15.7.3.10.2** Furnaces shall be checked prior to use and at regular intervals during use to identify undesirable hot spots.
- N 15.7.3.10.3*** Gas- or oil-fired furnaces shall be provided with combustion safety controls.
- N 15.7.3.10.4** All furnaces shall have two sets of temperature controls operating independently.
- N 15.7.3.10.4.1** One set of temperature controls shall maintain the desired operating temperature.
- N 15.7.3.10.4.2*** The other set of temperature controls, operating as a high-temperature limit control, shall cut off fuel or power to the heat-treating furnace at a temperature above the desired operating temperature.
- N 15.7.3.10.5** Magnesium parts to be put in a heat-treating furnace shall be free of magnesium turnings, chips, and swarf.
- N 15.7.3.10.6** Combustible spacers on pallets shall not be used in a heat-treating furnace.
- N 15.7.3.10.7*** Aluminum parts, sheets, or separators shall not be included in a furnace load of magnesium.
- N 15.7.3.10.8** There shall be strict adherence to the heat-treating temperature cycle recommended by the alloy manufacturer.
- N 15.7.3.10.9*** Molten salt baths containing nitrates or nitrites shall not be used for heat-treating magnesium alloys.
- N 15.7.3.10.10*** Magnesium and aluminum metals shall be segregated and easily identified to avoid the possibility of accidental immersion of magnesium alloys in salt baths used for aluminum.
- N 15.7.3.10.11*** Furnaces used to heat magnesium or magnesium alloys shall be inspected and cleaned as necessary to remove any accumulation of loose iron oxide scale.
- N 15.8 Storage and Handling.**
- N 15.8.1 Aluminum.**
- N 15.8.1.1 Storage of Aluminum Powder.** When aluminum powder is stored in sealed containers, the procedures of 15.8.1.1.1 through 15.8.1.1.7 shall apply.
- N 15.8.1.1.1** Containers from which a portion of powder has been removed shall be carefully covered and resealed.

- N 15.8.1.1.2** Containers shall be kept free of contact with water or moisture.
- N 15.8.1.1.3** Aluminum powder packed in sealed containers shall be permitted to be stored in commercial or public warehouses if they are of fire-resistive, noncombustible, or limited combustible construction as defined in NFPA 220 or are of other construction types protected with an automatic sprinkler system.
- N 15.8.1.1.4*** Aluminum powder shall be segregated from incompatible materials and combustible materials.
- N 15.8.1.1.5** When aluminum powder is stored in sealed containers, storage shall be limited to one-drum tiers per pallet with a height of no more than four pallet loads.
- N 15.8.1.1.5.1** Stacked storage shall be arranged to ensure stability.
- N 15.8.1.1.5.2** Aisles shall be provided for maneuverability of material-handling equipment, for ready accessibility, and to facilitate incipient fire-fighting operations.
- N 15.8.1.1.6** Leakage or condensation from roof, floor, walls, drains, steam, water lines, or radiators shall be avoided.
- N 15.8.1.1.7** Smoking and open flames shall be prohibited in areas where aluminum powder is stored.
- N 15.8.1.2 Scrap Handling, Storage, and Disposal. (Reserved)**
- N 15.8.1.3 Recycling.** Where a recycling facility handles aluminum in a combustible form, the requirements of Chapter 17 shall apply.
- N 15.8.1.4 Chip Processing. (Reserved)**
- N 15.8.2 Magnesium.**
- N 15.8.2.1 Storage of Magnesium Solids.**
- N 15.8.2.1.1* Storage of Pigs, Ingots, and Billets.**
- N 15.8.2.1.1.1** The size of piles of magnesium pigs, ingots, and billets shall be limited.
- N (A)** Minimum aisle widths shall be based on the height of the pile per 15.8.2.1.1.2(H).
- N (B)** The pile height shall not exceed 7.1 m (20 ft).
- N 15.8.2.1.1.2 Yard (Outdoor) Storage.**
- N (A)** Magnesium ingots shall be carefully piled on firm and generally level areas to prevent tilting or toppling.
- N (B)** Storage areas and yard pavements shall be well drained.
- N (C)** The storage area shall be kept free of grass, weeds, and accumulations of combustible materials.
- N (D)** Combustible flooring or supports shall not be used under piles of ingots.
- N (E)** The quantity of magnesium stored in any pile shall be kept to a minimum.
- N (F)** In no case, other than under the conditions of 15.8.2.1.1.2(G), shall the amount of magnesium stored exceed 45,400 kg (100,000 lb).
- N (G)** The quantities of magnesium stored shall be permitted to be increased up to a maximum of 454,000 kg (1,000,000 lb) per pile when the following requirements are met:
- (1) Provision has been made for drainage of water away from stored material.
 - (2) The aisle widths are equal to the pile height plus 3.1 m (10 ft) but no less than 4.5 m (15 ft).
 - (3) The piles are not more than 3.1 m (10 ft) wide.
- N (H)** Aisle width shall be at least one-half the height of the piles and shall be at least 3.1 m (10 ft).
- N (I)** Readily combustible material shall not be stored within a distance of 7.7 m (25 ft) from any pile of magnesium ingots.
- N (J)** An open space equal to the height of the piles plus 3.1 m (10 ft) shall be provided between the stored magnesium ingots and adjoining property lines where combustible material or buildings are exposed or where the adjacent occupancy can provide fire exposure to the magnesium.
- N 15.8.2.1.1.3* Indoor Storage.**
- N (A)** Indoor storage shall be in buildings of noncombustible construction.
- N (B)** Floors shall be well drained to prevent accumulations of water in puddles.
- N (C)** Supports and pallets used under piles of magnesium ingots shall be noncombustible.
- N (D)** The quantity of magnesium ingots stored in any one pile shall be kept to a minimum.
- N (E)** In no case, other than under the conditions of 15.8.2.1.1.3(F), shall the amount of magnesium stored exceed 23,000 kg (50,000 lb).
- N (F)** The quantities of magnesium stored shall be permitted to be increased up to a maximum of 227,800 kg (500,000 lb) per pile when the following requirements are met:
- (1) The piles are not more than 3.1 m (10 ft) wide.
 - (2)* The building is sprinklered if combustible materials are stored without the benefit of separation by fire wall or fire barrier wall from the magnesium storage.
- N (G)** Aisle widths shall comply with 15.8.2.1.1.2(H).
- N (H)** Combustible material shall not be stored within a distance of 7.7 m (25 ft) from any pile of magnesium pigs, ingots, and billets.
- N 15.8.2.1.2 Storage of Heavy Castings.**
- N 15.8.2.1.2.1** Except under the conditions of 15.8.2.1.2.2, buildings used for the storage of heavy magnesium castings shall be of noncombustible construction.
- N 15.8.2.1.2.2** Storage shall be permitted in buildings of combustible construction if the buildings are fully protected by an automatic sprinkler system.
- N 15.8.2.1.2.3* Floors** shall be of noncombustible construction and shall be well drained to prevent accumulations of water in puddles.
- N 15.8.2.1.2.4** All magnesium castings shall be clean and free of chips or fine particles of magnesium when being stored.

N 15.8.2.1.2.5 Storage Piles.

(A) The size of storage piles of heavy magnesium castings, either in cartons or crates or free of any packing material, shall be limited to 36 m³ (1270 ft³).

(B) Aisles shall be maintained to allow inspection and effective use of fire protection equipment.

N 15.8.2.1.2.6 Aisle width shall be at least one-half the height of the piles and shall be at least 3.1 m (10 ft).

N 15.8.2.1.2.7* Automatic sprinkler protection shall be permitted to be installed in magnesium storage buildings where combustible cartons, crates, or other packing materials are present.

N 15.8.2.1.3 Storage of Light Castings.**N 15.8.2.1.3.1 Building Construction.**

(A) Except under the conditions of 15.8.2.1.3.1(B), light magnesium castings shall be stored in noncombustible buildings and shall be segregated from other storage by 7.7 m (25 ft).

(B) Storage of light castings shall be permitted in buildings of combustible construction if the buildings are fully protected by an automatic sprinkler system. (See 15.8.2.1.3.5.)

N 15.8.2.1.3.2 Piles of stored light magnesium castings, either in cartons or crates or without packing, shall be limited in size to 28 m³ (1000 ft³).

N 15.8.2.1.3.3 Light castings shall be segregated from other combustible materials and shall be kept away from flames or sources of heat capable of causing ignition.

N 15.8.2.1.3.4 Aisle widths shall be at least one-half the height of the piles and shall be at least 3.1 m (10 ft).

N 15.8.2.1.3.5* Automatic sprinkler protection shall be permitted to be installed in magnesium storage buildings where combustible cartons, crates, or packing materials are present.

N 15.8.2.1.4 Storage in Racks or Bins.

N 15.8.2.1.4.1 Racks shall be permitted to be extended along walls in optional lengths.

N 15.8.2.1.4.2 Aisle spaces in front of racks shall be equal to the height of the racks.

N 15.8.2.1.4.3 All aisle spaces shall be kept clear.

N 15.8.2.1.4.4 Combustible rubbish, spare crates, and separators shall not be allowed to accumulate within the rack space.

N 15.8.2.1.4.5 Separators and metal sheets shall not be stacked on edge and leaned against racks, because they will prevent heat from a small fire from activating automatic sprinklers and will act as shields against sprinkler discharge.

N 15.8.2.1.5 Storage of Scrap Magnesium.

N 15.8.2.1.5.1 Paragraph 15.8.2.1.5 shall apply to the storage of scrap magnesium in the form of solids, chips, turnings, swarf, or other fine particles.

N 15.8.2.1.5.2 Buildings used for the indoor storage of magnesium scrap shall be of noncombustible construction.

N 15.8.2.1.5.3 Dry magnesium scraps shall be kept well separated from other combustible materials.

(A) Scraps shall be kept in covered steel or other noncombustible containers and shall be kept in such manner or locations that they will not become wet.

(B) Outside storage of magnesium fines shall be permitted if such storage is separated from buildings or personnel and great care is exercised to prevent the fines from becoming wet.

N 15.8.2.1.5.4* Wet magnesium scrap (chips, fines, swarf, or sludge) shall be kept under water in a covered and vented steel container at an outside location.

(A) Sources of ignition shall be kept away from the top of the container and the vent.

(B) Containers shall not be stacked.

N 15.8.2.1.5.5 Storage of dry scrap in quantities greater than 1.4m³ (50 ft³) [six 208 L drums (six 55 gal drums)] shall be kept separate from other occupancies by fire-resistive construction without window openings or by an open space of at least 15m (50 ft), and such buildings shall be well ventilated to avoid the accumulation of hydrogen in the event that the scrap becomes wet.

N 15.8.2.1.5.6 Solid magnesium scrap, such as clippings and castings, shall be stored in noncombustible bins or containers, pending salvage.

N 15.8.2.1.5.7 Oily rags, packing materials, and similar combustibles shall not be permitted in storage bins or areas that store solid magnesium scrap.

N 15.8.2.1.5.8 The use of automatic sprinklers in magnesium scrap storage buildings or areas shall be prohibited.

N 15.8.2.1.6 Storage of Magnesium Powder.

N 15.8.2.1.6.1 Buildings used to store magnesium powder shall be of noncombustible, single-story construction.

N 15.8.2.1.6.2 The use of automatic sprinklers in magnesium powder storage buildings shall be strictly prohibited.

N 15.8.2.1.6.3 Magnesium powder shall be kept well separated from other combustible or reactive metals.

N 15.8.2.1.6.4 Magnesium powder shall be stored in closed steel drums or other closed noncombustible containers, and the containers shall be stored in dry locations.

N 15.8.2.1.6.5 Magnesium powder storage areas shall be kept dry and shall be checked for water leakage.

N 15.8.2.1.6.6* Where magnesium powder in drums is stacked for storage, the maximum height shall not exceed 5.5 m (18 ft).

(A) Storage shall be stacked in a manner that ensures stability.

(B) Under no circumstances shall containers be allowed to topple over.

N 15.8.2.1.7 Storage of Other Magnesium Products.

N 15.8.2.1.7.1* Paragraph 15.8.2.1.7 shall apply to the storage of parts and components in warehouses, wholesale facilities, factories, and retail establishments in which magnesium makes up 50 percent or more of the article's composition on a volumetric basis or where the magnesium-containing assemblies as pack-

aged or stored exhibit the burning characteristics of magnesium.

N 15.8.2.1.7.2 Storage in quantities greater than 1.4 m³ (50 ft³) shall be separated from storage of other materials that are either combustible or are contained in combustible containers by aisles with a minimum width equal to the height of the piles of magnesium products.

N 15.8.2.1.7.3 Magnesium products stored in quantities greater than 28 m³ (1000 ft³) shall be separated into piles, each not larger than 28m³ (1000 ft³), with the minimum aisle width equal to the height of the piles but in no case less than 3.1 m (10 ft).

N 15.8.2.1.7.4* The storage area shall be protected by automatic sprinklers in any of the following situations:

- (1) Where storage in quantities greater than 28 m³ (1000 ft³) is contained in a building of combustible construction
- (2) Where magnesium products are packed in combustible crates or cartons
- (3) Where other combustible storage is within 9 m (30 ft) of the magnesium

N 15.8.2.2 Scrap Handling, Storage, and Disposal. (Reserved)

N 15.8.2.3 Recycling. The requirements of Chapter 17 shall apply to processes handling recycled magnesium, which is in a combustible form.

N 15.8.2.4 Chip Processing. (Reserved)

N 15.8.3 Niobium.

N 15.8.3.1 Storage of Product.

N 15.8.3.1.1 Storage with Incompatible Materials. Niobium shall not be stored in an area with incompatible materials.

N 15.8.3.1.2 Scrap Storage.

N 15.8.3.1.2.1 Open storage of sheet, plate, forgings, or massive pieces of scrap shall be permitted.

N 15.8.3.1.2.2 Storage of scrap, chips, fines, and dust that are ignitable shall be isolated and segregated from other combustible materials to prevent propagation of a fire.

N 15.8.3.1.3 Powder Storage.

N 15.8.3.1.3.1* Niobium powder shall be stored in covered containers.

N 15.8.3.1.3.2 Niobium storage areas shall be free of combustible goods (other than the container used to store the niobium) and plainly marked with “No Open Flame” signs.

N 15.8.3.1.3.3 Where drums or other containers are used for storage, storage shall be limited to a height that would require no more than three movements using available equipment to move a stack.

N 15.8.3.1.3.4 Under no circumstances shall stack height exceed 3.1 m (10 ft).

N 15.8.3.1.3.5 Stacked storage shall be arranged to ensure stability.

N 15.8.3.1.3.6 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate fire-fighting operations.

N 15.8.3.1.4 Other Production Materials.

N 15.8.3.1.4.1 Magnesium Operations. All magnesium storage, handling, and processing operations in niobium production operations shall be in accordance with the requirements of 15.8.2.

N 15.8.3.1.4.2 Flammable and Combustible Liquids. Storage and handling of flammable and combustible liquids shall be in accordance with NFPA 30.

N 15.8.3.2 Scrap Handling, Storage, and Disposal. Scrap handling, storage, and disposal shall be in accordance with Chapter 17.

N 15.8.3.3 Recycling. Recycling shall be in accordance with Chapter 17.

N 15.8.3.4 Chip Processing. (Reserved)

N 15.8.4 Tantalum.

N 15.8.4.1 Storage of Product.

N 15.8.4.1.1 Storage of Incompatible Materials. Tantalum shall not be stored in an area with incompatible materials.

N 15.8.4.1.2 Sponge Storage. (Reserved)

N 15.8.4.1.3 Powder Storage.

N 15.8.4.1.3.1* Tantalum powder shall be stored in covered containers.

N 15.8.4.1.3.2 Tantalum storage areas shall be free of combustible goods (other than the container used to store the tantalum), well ventilated, equipped with the required fire protection equipment, and plainly marked with “No Open Flame” signs.

N 15.8.4.1.3.3 Where drums or other containers are used for storage, storage shall be limited to a height that would require no more than three movements using available equipment to remove a stack and no stack shall exceed 3.1 m (10 ft) in height.

N 15.8.4.1.3.4 Stacked storage shall be arranged to ensure stability.

N 15.8.4.1.3.5 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate fire-fighting operations.

N 15.8.4.1.4 Storage of Other Production Materials Associated with Tantalum.

N 15.8.4.1.4.1 Magnesium Operations. All magnesium storage, handling, and processing operations in tantalum production operations shall be in accordance with the requirements of 15.8.2.

N 15.8.4.1.4.2 Sodium Operations. All sodium storage, handling, and processing operations shall be in accordance with Chapter 14.

N 15.8.4.1.4.3 Flammable and Combustible Liquids. Storage and handling of flammable and combustible liquids shall be in accordance with NFPA 30.

N 15.8.4.2 Scrap Handling, Storage, and Disposal.

N 15.8.4.2.1 Open storage of sheet, plate, forgings, or massive pieces of scrap shall be permitted.

N 15.8.4.2.2 Storage of scrap, chips, fines, and dust that are ignitable shall be isolated and segregated from other combustible materials to prevent propagation of a fire.

N 15.8.4.3 Recycling. (Reserved)

N 15.8.4.4 Chip Processing. (Reserved)

N 15.8.5 Titanium.

N 15.8.5.1 Storage of Product.

N 15.8.5.1.1 Magnesium for use in the sponge producing process shall be stored in accordance with the requirements of 15.8.2.

N 15.8.5.1.2 Chlorine shall be handled and stored in accordance with accepted industry practice.

N 15.8.5.1.3 Bulk containers of liquid titanium tetrachloride (TiCl_4) shall be stored in a well-ventilated place located away from areas of acute fire hazard. Containers shall be identified plainly and sealed tightly until used.

N 15.8.5.1.4 General Storage.

N 15.8.5.1.4.1 Titanium storage areas shall be kept free of combustible materials, shall be well-ventilated, shall be equipped with required fire protection equipment as specified in Section 15.9, and shall be plainly marked with “No Smoking” signs.

N 15.8.5.1.4.2 Where titanium is collected or stored in containers, material handling equipment with sufficient capability to remove any container from the immediate area in the case of an emergency shall be readily available.

N 15.8.5.1.4.3 Where drums are used, storage shall be limited to one-drum tiers per pallet, with a height of not more than four pallet loads.

N 15.8.5.1.4.4 Stacked storage shall be positioned in such a manner as to ensure stability.

N 15.8.5.1.4.5 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate fire-fighting operations.

N 15.8.5.1.4.6 The maximum weight of material (per pallet or container) shall be capable of being moved by the available equipment.

N 15.8.5.1.4.7 Open storage of sheet, plate, forgings, or massive pieces of scrap presents no fire risk and shall be permitted.

N 15.8.5.1.4.8 Storage of materials in closed noncombustible containers shall be permitted.

N 15.8.5.1.5 Sponge Storage.

N 15.8.5.1.5.1 Titanium sponge shall be stored in closed metal containers.

N 15.8.5.1.5.2 Containers shall not be sealed unless they are inerted.

N 15.8.5.1.5.3 Storage of sponge shall comply with 15.8.5.1.4.

N 15.8.5.1.5.4 Sealed titanium-reduction vessels shall be permitted to be water cooled and shall be designed to prevent water from entering the reaction vessel.

N 15.8.5.2 Scrap Handling, Storage, and Disposal.

N 15.8.5.2.1 Residue from casting furnaces shall be placed in steel boxes and moved outside the building.

N 15.8.5.2.2 Covered, vented steel containers shall be used to transport collected sludge (from wet dust collectors) to a safe storage area or for disposal.

N 15.8.5.2.3 Sludge shall be disposed of in accordance with local, state, and federal regulations.

N 15.8.5.3 Recycling. Recycling shall be in accordance with Chapter 17.

N 15.8.5.4 Chip Processing. (Reserved)

N 15.8.6 Zirconium and Hafnium.

N 15.8.6.1 Storage of Product.

N 15.8.6.1.1 Magnesium for use in the sponge producing process shall be stored in accordance with the requirements of 15.8.2.

N 15.8.6.1.2 Chlorine shall be handled and stored in accordance with accepted industry practice.

N 15.8.6.1.3 Bulk containers of liquid zirconium tetrachloride (ZrCl_4) or hafnium or hafnium tetrachloride (HfCl_4) shall be stored in a well-ventilated place located away from areas of acute fire hazard. Containers shall be identified plainly and sealed tightly until used.

N 15.8.6.1.4 General Storage.

N 15.8.6.1.4.1 Zirconium or hafnium storage areas shall be kept free of combustible materials, shall be well-ventilated, shall be equipped with required fire protection equipment as specified in 15.9.7, and shall be plainly marked with “No Smoking” signs.

N 15.8.6.1.4.2 Where zirconium or hafnium is collected or stored in containers, material handling equipment with sufficient capability to remove any container from the immediate area in the case of an emergency shall be readily available.

N 15.8.6.1.4.3 Where drums are used, storage shall be limited to one-drum tiers per pallet with a height of not more than four pallet loads.

N 15.8.6.1.4.4 Stacked storage shall be positioned in such a manner as to ensure stability.

N 15.8.6.1.4.5 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate fire-fighting operations.

N 15.8.6.1.4.6 The maximum weight of material (per pallet or container) shall be capable of being moved by the available equipment.

N 15.8.6.1.4.7 Open storage of sheet, plate, forgings, or massive pieces of scrap presents no fire risk and shall be permitted.

N 15.8.6.1.4.8 Storage of materials in closed noncombustible containers shall be permitted except as noted for sponge. (See 15.8.6.1.5.2.)

N 15.8.6.1.5 Sponge Storage.

N 15.8.6.1.5.1 Zirconium or hafnium sponge shall be stored in closed metal containers.

- N 15.8.6.1.5.2** Containers shall not be sealed unless they are inerted.
- N 15.8.6.1.5.3** Storage of sponge shall comply with 15.8.6.1.4.
- N 15.8.6.1.5.4** Sealed zirconium or hafnium-reduction vessels shall be permitted to be water cooled and shall be designed to prevent water from entering the reaction vessel.
- N 15.8.6.2 Scrap Handling, Storage, and Disposal.**
- N 15.8.6.2.1** Residue from casting furnaces shall be placed in steel boxes and moved outside the building.
- N 15.8.6.2.2** Covered, vented steel containers shall be used to transport collected sludge (from wet dust collectors) to a safe storage area or for disposal.
- N 15.8.6.2.3** Sludge shall be disposed of in accordance with local, state, and federal regulations.
- N 15.8.6.3 Recycling.** Recycling shall be in accordance with Chapter 17.
- N 15.8.6.4 Chip Processing. (Reserved)**
- N 15.9 Fire and Explosion Prevention.**
- N 15.9.1** Fire and explosion protection shall be in accordance with Chapter 8.
- N 15.9.2 Aluminum.**
- N 15.9.2.1 Scope.** Subsection 15.9.2 shall apply to new and existing facilities where combustible aluminum dusts, pastes, and powders are present.
- N 15.9.2.2 Control of Ignition Sources.** Control of ignition sources shall be in accordance with Chapter 10.
- N 15.9.2.3 Hot Work Operations.** Hot work operations in facilities covered by this standard shall be in accordance with Section 10.2.
- N 15.9.2.4 Control of Combustible Materials.**
- N 15.9.2.4.1** Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30.
- N 15.9.2.4.1.1** Forge presses, heavy grinders, and other milling equipment operated by hydraulic systems of 189 L (50 gal) or greater shall use a less hazardous hydraulic fluid with a flash point greater than 93°C (200°F).
- N 15.9.2.4.1.2** Dipping and coating applications of flammable or combustible liquids shall be done in accordance with NFPA 34.
- N 15.9.2.4.1.3** Spray application of flammable or combustible liquids shall be done in accordance with NFPA 33.
- N 15.9.2.4.2 Ordinary Combustible Storage.**
- N 15.9.2.4.2.1** Ordinary combustible materials, such as paper, wood, cartons, and packing material, shall not be stored or allowed to accumulate in processing areas unless necessary for the process, and then only in designated areas.
- N 15.9.2.4.2.2** Ordinary combustible materials shall not be discarded in containers used for the collection of combustible metal waste.
- N 15.9.2.4.3 Removal of Combustible Metal Chips, Fines, Swarf, Paste, Powder, Dust, and Sweepings.**
- N 15.9.2.4.3.1** All combustible metal chips, lathe turnings, and swarf shall be collected in closed-top metal containers and removed daily, as a minimum, to a safe storage or disposal area.
- N 15.9.2.4.3.2** Open storage of sponge, chips, fines, and dust that are readily ignitable shall be isolated and segregated from other combustible materials and metal scrap to prevent propagation of a fire.
- N 15.9.2.5 Inspection, Maintenance, and Training.**
- N 15.9.2.5.1 Safety Inspection.** A thorough inspection of the operating area shall take place on an as-needed basis to help ensure that the equipment is in good condition and that proper work practices are being followed.
- N 15.9.2.5.1.1** The inspection shall be conducted at least quarterly but shall be permitted to be done more often.
- N 15.9.2.5.1.2** The inspection shall be conducted by a person(s) knowledgeable in the proper practices, who shall record the findings and recommendations.
- N 15.9.2.5.2* Employee Training Program.** Training programs shall be instituted to inform employees about the hazards involved in the manufacture of aluminum powder, paste, or granules and the hazards involved in processing or finishing operations that generate fine combustible aluminum dust, as appropriate to the operation.
- N 15.9.2.5.3 Emergency Procedures.**
- N 15.9.2.5.3.1** Emergency procedures to be followed in case of fire or explosion shall be established.
- N 15.9.2.5.3.2* All employees shall be trained in the emergency procedures specified in 15.9.2.5.3.1.**
- N 15.9.3 Magnesium.**
- N 15.9.3.1 Scope.**
- N 15.9.3.1.1** The provisions of 15.9.3 shall apply to all new and existing magnesium production processing, handling, and storage operations.
- N 15.9.3.1.2** Buildings shall comply with the applicable provisions of NFPA 101.
- N 15.9.3.2 Control of Ignition Sources.** Control of ignition sources shall be in accordance with Chapter 10.
- N 15.9.3.3* Hot Work.**
- N 15.9.3.3.1** Hot work operations shall be in accordance with Section 10.2.
- N 15.9.3.3.2** Hot work permits shall be required in designated areas that contain exposed magnesium chips, powder, or sponge.
- N 15.9.3.3.3** All hot work areas that require a permit shall be thoroughly cleaned of magnesium chips, powder, or sponge before hot work is performed.
- N 15.9.3.4 Control of Combustible Materials.**
- N 15.9.3.4.1** Ordinary combustible materials, such as paper, wood, cartons, and packing material, shall not be stored or allowed to accumulate in magnesium-processing areas.

N 15.9.3.4.2 The requirement of 15.9.3.4.1 shall not apply where ordinary combustible materials are necessary for the process and are stored in designated areas.

N 15.9.3.4.3* Ordinary combustible materials shall not be discarded in containers used for the collection of magnesium sponge, chips, or powder, with the exception of floor sweepings from magnesium operations, which shall be permitted to contain small amounts of ordinary combustible materials.

N 15.9.3.5 Inspection, Maintenance, and Training.

N 15.9.3.5.1 Periodic inspections shall be conducted, as frequently as conditions warrant, to detect the accumulation of excessive magnesium chips or powder on any portions of buildings or machinery not regularly cleaned during daily operations.

N 15.9.3.5.2 Records of the inspections specified in 15.9.3.5.1 shall be kept.

N 15.9.4 Niobium.

N 15.9.4.1 Control of Ignition Sources. Control of ignition sources shall be in accordance with Chapter 10.

N 15.9.4.2* Hot Work Operations. Hot work, exclusive of process activities, shall not be permitted in areas where combustible forms of niobium are present until exposed equipment has been cleaned thoroughly.

N 15.9.4.3 Control of Combustible Material.

N 15.9.4.3.1 Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30.

N 15.9.4.3.1.1 Forge presses, heavy grinders, and other milling equipment operated by hydraulic systems of 189 L (50 gal) or greater shall use a less hazardous hydraulic fluid with a flash point greater than 93°C (200°F).

N 15.9.4.3.1.2 Dipping and coating applications of flammable or combustible liquids shall be done in accordance with NFPA 34.

N 15.9.4.3.1.3 Spray application of flammable or combustible liquids shall be done in accordance with NFPA 33.

N 15.9.4.4 Ordinary Combustible Storage.

N 15.9.4.4.1 Ordinary combustible materials, such as paper, wood, cartons, and packing material, shall not be stored or allowed to accumulate in processing areas unless necessary for the process, and then only in designated areas.

N 15.9.4.4.2 Ordinary combustible materials shall not be discarded in containers used for the collection of combustible metal waste.

N 15.9.4.4.3 Removal of Combustible Metal Chips, Fines, Swarf, Paste, Powder, Dust, and Sweepings.

N 15.9.4.4.3.1 All combustible metal chips, lathe turnings, and swarf shall be collected in closed-top metal containers and removed a minimum of once daily, to a safe storage or disposal area.

N 15.9.4.4.3.2 Open storage of sponge, chips, fines, and dust that are readily ignitable shall be isolated and segregated from other combustible materials and metal scrap to prevent propagation of a fire.

N 15.9.4.5 Inspection, Maintenance, and Testing. (Reserved)

N 15.9.5 Tantalum.

N 15.9.5.1 Scope. The provisions of 15.9.5 shall apply to all new and existing tantalum powder production processes, handling, and storage operations.

N 15.9.5.2 Control of Ignition Sources. Control of ignition sources shall be in accordance with Chapter 10.

N 15.9.5.3 Hot Work Operations. Hot work operations shall be in accordance with Section 10.2.

N 15.9.5.4 Control of Combustible Materials.

N 15.9.5.4.1 Ordinary combustible materials, such as paper, wood, cartons, and packing material, shall not be stored or allowed to accumulate in tantalum-processing areas.

N 15.9.5.4.2 Where ordinary combustible materials are necessary for the process and are stored in designated areas, 15.9.5.4.1 shall not apply.

N 15.9.5.4.3 Ordinary combustible materials shall not be discarded in containers used for the collection of chips or powder.

N 15.9.5.4.4 Floor sweepings from tantalum operations shall be permitted to contain small amounts of ordinary combustible materials and shall be stored in separate containers.

N 15.9.5.4.5 Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30.

N 15.9.5.4.6 Where tantalum powder is collected or stored in containers, material-handling equipment with sufficient capability to remove any container from the immediate area in the case of an emergency shall be available.

N 15.9.5.5 Inspection, Maintenance, and Testing.

N 15.9.5.5.1 Periodic inspections shall be conducted as frequently as conditions warrant to detect the accumulation of excessive tantalum chips or powder on any portions of buildings or machinery not regularly cleaned during daily operations.

N 15.9.5.5.2 Records of the inspections specified in 15.9.5.5.1 shall be kept.

N 15.9.6 Titanium.

N 15.9.6.1 Control of Ignition Sources. Control of ignition sources shall be in accordance with Chapter 10.

N 15.9.6.2 Hot Work Operations. Hot work operations shall be in accordance with Section 10.2.

N 15.9.6.3 Control of Combustible Materials.

N 15.9.6.3.1 Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30.

N 15.9.6.3.1.1 Forge presses, heavy grinders, and other milling equipment operated by hydraulic systems of 189 L (50 gal) or greater shall use a less hazardous hydraulic fluid with a flash point greater than 93°C (200°F).

N 15.9.6.3.1.2 Dipping and coating applications of flammable or combustible liquids shall be done in accordance with NFPA 34.

N 15.9.6.3.1.3 Spray application of flammable or combustible liquids shall be done in accordance with NFPA 33.

N 15.9.6.3.2 Ordinary Combustible Storage.

N 15.9.6.3.2.1 Ordinary combustible materials, such as paper, wood, cartons, and packing material, shall not be stored or allowed to accumulate in processing areas unless necessary for the process, and then only in designated areas.

N 15.9.6.3.2.2 Ordinary combustible materials shall not be discarded in containers used for the collection of combustible metal waste.

N 15.9.6.3.3 Removal of Combustible Metal Chips, Fines, Swarf, Paste, Powder, Dust, and Sweepings.

N 15.9.6.3.3.1 All combustible metal chips, lathe turnings, and swarf shall be collected in closed-top metal containers and removed daily, as a minimum, to a safe storage or disposal area.

N 15.9.6.3.3.2 Open storage of sponge, chips, fines, and dust that are readily ignitable shall be isolated and segregated from other combustible materials and metal scrap to prevent propagation of a fire.

N 15.9.6.3.4 Inspection, Maintenance, and Training.

N 15.9.6.3.4.1 Regular inspections shall be conducted to detect the accumulation of excessive titanium dust, chips, or fines on any portions of buildings or machinery not regularly cleaned in daily operations.

N 15.9.6.3.4.2 Records shall be kept of the inspections conducted in 15.9.6.3.4.1.

N 15.9.7 Zirconium and Hafnium.

N 15.9.7.1 Control of Ignition Sources. Control of ignition sources shall be in accordance with Chapter 10.

N 15.9.7.2 Hot Work Operations. Hot work operations shall be in accordance with Section 10.2.

N 15.9.7.3 Control of Combustible Materials. (Reserved)

N 15.9.7.4 Inspection, Maintenance, and Training.

N 15.9.7.4.1 Regular inspections shall be conducted to detect the accumulation of excessive zirconium or hafnium dust, chips, or fines on any portions of buildings or machinery not regularly cleaned in daily operations.

N 15.9.7.4.2 Records shall be kept of the inspections conducted in 15.9.7.4.1.

N 15.10 Other. (Reserved)

Chapter 16 Other Metals

16.1 General Provisions.

16.1.1 Retroactivity. The requirements of 16.1.2 through 16.1.5 shall apply to new and existing facilities.

Δ 16.1.2 Housekeeping. Housekeeping shall be in accordance with Chapter 9.

16.1.3 Personal Protective Equipment (PPE). PPE shall be in accordance with Section 4.6.

16.1.4 Reactivity. It shall be the responsibility of the facility to evaluate processes and materials for potentially dangerous reactions that could occur in the course of their operations.

16.1.4.1* Thermite Reactions. Caution shall be exercised in the mixing of reduced fines or molten material with metal oxides that exothermically react with the reduced metal.

16.1.4.2 Eutectic Reactions. (Reserved)

16.1.4.3 Contact with Water. (Reserved)

16.1.5 Management of Change. Management of change shall be in accordance with Section 4.4.

16.1.6 Alternative Methodologies. (Reserved)

16.1.7 Test Results. (Reserved)

16.1.8 Other. (Reserved)

16.2 Facility Design Requirements.

16.2.1 Building Construction.

16.2.1.1 Buildings housing combustible metals operations shall be of noncombustible construction, unless a hazard analysis has been performed that shows that noncombustible construction is not required.

Δ 16.2.1.2 Buildings shall comply with the applicable provisions of NFPA 101.

16.2.1.3 Building areas where combustible metal dusts might be present shall be designed so that all internal surfaces are accessible, to facilitate cleaning.

16.2.1.3.1 All walls of areas where fugitive dust can be produced shall have a smooth finish and shall be sealed so as to leave no interior or exterior voids where dust can infiltrate and accumulate.

16.2.1.3.2 The annulus of all pipe, conduit, and ventilation penetrations shall be sealed.

16.2.1.4 Roofs.

16.2.1.4.1 Roofs of buildings that house combustible metal dust-producing operations shall be supported on girders or structural members designed to minimize surfaces on which dust can collect.

16.2.1.4.2* Interior surfaces where dust accumulations can occur shall be designed and constructed to facilitate cleaning and minimize combustible dust accumulations.

16.2.1.5 Floors, elevated platforms, balconies, and gratings shall be hard surfaced and installed with a minimum number of joints in which powder or dust can collect.

Δ 16.2.1.6* Explosion venting in accordance with NFPA 68 shall be required for all buildings or building areas where combustible metal powders or dusts are present, unless a hazard analysis has been performed that shows that explosion venting is not required.

Δ 16.2.1.7 All doors in interior fire-rated partitions shall be listed, self-closing fire doors installed in accordance with NFPA 80.

16.2.1.8 Buildings or portions of buildings of noncombustible construction used principally for combustible-metal storage or

handling shall not be permitted to be equipped with automatic sprinkler protection.

- ▲ **16.2.1.9** Sprinkler systems installed in accordance with NFPA 13 shall be permitted in areas where combustibles other than combustible metals create a more severe hazard than the combustible metals and where acceptable to an authority having jurisdiction that is knowledgeable of the hazards associated with the combustible metal.

16.2.1.10 Fittings used on outlets of compressed-air and inert-gas lines shall not be interchangeable, to prevent potential explosions caused by inadvertently using compressed air in place of low-pressure inert gas.

16.2.1.11 Water leakage inside or into any building where the water can contact water-reactive combustible metal shall be prevented.

16.2.1.12 One or more remotely located control stations shall be provided to allow the selective shutdown of process equipment in an emergency.

16.2.1.13 Enclosed Passageways.

- ▲ **16.2.1.13.1** Where buildings or process areas are interconnected by enclosed passageways, the passageways shall be designed in accordance with NFPA 68 to prevent propagation of an explosion or fire from one unit to another.

- ▲ **16.2.1.13.2** All enclosed passageways that can be occupied and that connect with one or more processing areas shall be provided with means of egress in accordance with NFPA 101.

16.2.1.14 Heating and Cooling of Buildings.

16.2.1.14.1 Buildings shall be permitted to be heated by indirect hot-air heating systems, by bare-pipe heating systems using steam or hot water as the heat transfer medium, or by listed electric heaters.

16.2.1.14.2 Indirect hot air shall be permitted if the heating unit is located in a combustible metal dust-free area adjacent to the room or area where heated air is required.

16.2.1.14.3 Fans or blowers used to convey the heated or cooled air shall be located in a combustible metal dust-free location.

16.2.1.14.4 The air supply shall be taken from outside or from a location that is free of combustible metal dust.

16.2.1.14.5 Make-up air for building heating or cooling shall have a dew point low enough to ensure that no free moisture can condense at any point where the air is in contact with combustible metal dust or powder.

16.2.1.14.6 The requirements of 16.2.1.14.1 through 16.2.1.14.5 shall not apply to areas where metal is melted.

- ▲ **16.2.2 Fire Protection.** Fire protection shall be in accordance with Chapter 8.

- ▲ **16.2.3 Dust Collection.** Dust collection shall be in accordance with Chapter 11.

16.2.4 Hazard Analysis. Hazard analysis shall be in accordance with Section 4.5.

16.3 Primary Metal Production.

16.3.1 Reduction. (Reserved)

16.3.2 Melting and Casting.

16.3.2.1* Water-cooled vacuum arc furnaces shall be designed with safety interlock systems that will allow the furnace to operate only if there is sufficient cooling waterflow to prevent over-temperature of the melting crucible.

16.3.2.2 Vacuum arc furnace electrodes shall be firmly affixed to the electrode stinger in such a fashion that the electrode will not become detached during the melting operation.

16.3.2.3 Buildings used for the melting and casting of metals shall be noncombustible.

16.3.2.4 Floors shall be kept free of standing water.

16.3.2.5* All solid metal shall be thoroughly dried throughout by preheating or other methods prior to coming into contact with molten metal.

- ▲ **16.3.2.6** Ovens and furnaces shall comply with NFPA 86.

- ▲ **16.3.2.7** Fuel supply lines shall comply with NFPA 54.

- ▲ **16.3.2.8** Use of flammable and combustible liquids shall comply with NFPA 30.

16.3.2.9 Areas of furnaces that can come into contact with molten metal in the event of a runout shall be kept dry and free of metal oxides that exothermically react with the molten metal.

16.3.2.10 Crucible interiors and covers shall be maintained free of metal oxides scale that exothermically react with the molten metal.

16.3.2.11 Molten metal systems shall overflow or relieve to secondary containments designed to handle 110 percent of the largest expected failure and shall be provided with the means to prevent contact with incompatible materials.

16.3.2.12 Pots and Crucibles.

16.3.2.12.1 Melting pots and crucibles shall be inspected regularly.

16.3.2.12.2 Pots and crucibles that show evidence of possible failure or that allow molten metal to contact metal oxides that exothermically react with the molten metal, concrete, or other incompatible materials shall be repaired or discarded.

16.3.2.13 Ladles, skimmers, and sludge pans shall be thoroughly dried and preheated before contacting molten metal.

16.3.2.14 Extreme care shall be exercised in pouring metal castings, to avoid spillage.

16.3.2.15 All molds shall be thoroughly preheated before pouring.

16.3.2.16 Operators' Garments.

16.3.2.16.1 Operators in melting and casting areas where there is an opportunity for the operator to come into contact with molten metal shall wear flame-resistant clothing, high top safety shoes, and face protection.

16.3.2.16.2 Garments worn where molten metal is present shall have no exposed pockets or cuffs that could trap and retain metal.

16.3.3 Refining. (Reserved)

16.4 Powder Production.

16.4.1 Handling and Conveying of Powder.

16.4.1.1 Where powder is present, good housekeeping practices shall be maintained.

16.4.1.2 Powder shall be handled so as to avoid spillage and the creation of airborne dust.

16.4.1.3 Scoops, shovels, and scrapers used in the handling of powder shall be electrically conductive and shall be grounded when necessary, and hand tools shall be made of spark-resistant materials.

16.4.1.4 Each container for powders shall be conductive and covered while in storage or in transit.

16.4.1.5 When powders are being charged to or discharged from machines, the containers shall be bonded to the grounded machine.

16.4.1.6 When powder is being transferred between containers, the containers shall be bonded, and at least one of the containers shall be grounded.

16.4.2 Portable Containers.

16.4.2.1 In-plant transport of metal powders shall be done in covered conductive containers as described in 16.4.1.4.

16.4.3 Ductwork for Pneumatic Conveying Systems. Ductwork for pneumatic conveying systems shall be in accordance with 11.5.1.

16.4.4 Conveying Using an Inert Medium. Conveying using an inert medium shall be in accordance with 11.5.2.

16.4.5 Fan and Blower Construction and Arrangement. Fan and blower construction and arrangement shall be in accordance with 11.5.3.

16.4.6 Powder Collection. Powder collection shall be in accordance with Section 11.6.

16.5 End Users of Powder.

16.5.1 Powder Handling and Use.

16.5.1.1 Scope. The provisions of Section 16.5 shall apply to operations including, but not limited to, the use of powder in the production of paste, flake powders, powdered metallurgy component manufacturing, fireworks and pyrotechnics, propellants, plasma spray coating, chemical processing, and refractories.

16.5.1.2 Storage. Dry powder and paste shall be stored in accordance with the provisions of Section 16.9.

16.5.1.3* Handling. The requirements of Section 16.5 shall apply to both regular and “nondusting” grades of powder, as well as to paste.

▲ **16.5.1.4** Where powder or paste is used or handled, good housekeeping practices shall be maintained in accordance with Chapter 9.

16.5.1.5 Scoops, shovels, and scrapers used in the handling of powder and paste shall be electrically conductive and shall be grounded when necessary, and hand tools shall be made of spark-resistant materials.

16.5.1.6 Powered industrial trucks shall be selected in accordance with NFPA 505 and consistent with 16.2.1.

16.5.2 General.

16.5.2.1* Equipment shall be constructed to mitigate the potential for ignition of the powder.

16.5.2.2 A hazards analysis shall be performed for areas where powder is present to determine risk factors and appropriate controls.

16.5.2.3* Where the hazards analysis shows that controls are required to manage the risk of static generation and that static-dissipative flooring or static-dissipative floor mats are required, personnel shall wear static-dissipative footwear or equivalent grounding devices.

16.5.2.4* Where static-dissipative flooring or static-dissipative floor mats are required, personnel shall wear flame-resistant clothing designed to minimize the accumulation of powder.

16.5.2.5* Spark-resistant tools shall be used.

16.5.2.6 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in case of primary system failure.

16.5.3 Powder Storage.

16.5.3.1 Daily supplies of powder shall be allowed to be stored in the production area.

16.5.3.1.1 The powder shall be stored in covered containers and shall be segregated from other combustible materials.

16.5.3.1.2 The maximum capacity of the container shall be such that it can be moved by available equipment.

16.5.3.1.3 The containers shall be protected from damage.

16.5.3.2 Stacked Storage.

16.5.3.2.1 When powder is stored in sealed containers, stacked storage shall be arranged to ensure stability.

16.5.3.2.2 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate fire-fighting operations.

16.5.4 Dry Powder Handling.

16.5.4.1* Precautions shall be taken to prevent spills or dispersions that produce dust clouds.

▲ **16.5.4.2** Sintering furnaces that handle compacted powder shall be installed and operated in accordance with NFPA 86.

16.5.4.2.1 Powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

16.5.4.2.2 Furnaces shall be operated with inert atmospheres of argon or helium or under vacuum.

16.5.5 Handling of Wet Powder by End Users.

16.5.5.1 When water-wetted powder is air-dried at atmospheric pressure, the temperature shall not exceed 80°C (176°F).

16.5.5.2 When powders wetted with fluids other than water are air-dried, the temperature shall be governed by the characteristics of the fluid but shall not exceed 80°C (176°F).

16.5.5.3 When powders are dried under controlled atmospheric conditions (e.g., vacuum or inert atmosphere) and the temperature of the powder exceeds 80°C (176°F), the powder shall be cooled to less than 80°C (176°F) prior to exposure to air.

16.5.6 Heat Treatment and Passivation.

16.5.6.1 Equipment shall be designed, constructed, and **installed** to mitigate the potential for ignition and accumulation of the powder.

▲ **16.5.6.2** Fuel supply lines to gas-fired furnaces or other gas-fired equipment shall be installed and maintained in accordance with NFPA 54.

▲ **16.5.6.3** Furnaces shall comply with NFPA 86.

16.5.7* Personnel Safety Precautions.

16.5.7.1 The metal shall be handled only by trained personnel who are knowledgeable of the hazards associated with that particular metal.

16.5.7.2 Access to metal-handling areas by unauthorized personnel shall not be permitted.

16.5.7.3 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in case of primary system failure.

16.5.8 Powder Heat Treatment and Sintering.

16.5.8.1 After powder furnacing, the powder shall be passivated prior to exposure to air atmosphere.

16.5.8.2 Furnaced powder shall be cooled to 50°C (122°F) or less prior to starting passivation.

16.5.9* Heat Treatment and Sintering of Compacts.

16.5.9.1* Sintered compacts shall be cooled to 50°C (122°F) or less prior to removal from the furnace.

16.5.9.2 Sintered compacts shall be isolated from other combustible materials until their temperature has stabilized below 50°C (122°F).

16.5.10 Safety Precautions.

16.5.10.1 If the furnace's primary cooling source fails, an alternative system shall provide cooling for the furnace for any required cool-down time period.

16.5.10.2 The alternative cooling system specified in **16.5.10.1** shall be activated automatically upon failure of the main cooling source and shall be interlocked to prevent operation of the furnace.

16.6 Processing.

16.6.1 Machining and Operations.

16.6.1.1 Requirements for Machinery.

16.6.1.2 All combustible metal dust-producing machines and conveyors shall be designed, constructed, and operated so that fugitive dust is minimized.

16.6.1.3* All machinery shall be bonded and grounded to minimize accumulation of static electric charge.

16.6.1.4 Bearings.

16.6.1.4.1* Ball or roller bearings shall be sealed against dust.

16.6.1.4.2 Where exposed bearings are used, the bearings shall be protected to prevent ingress of combustible metal dust and shall have a lubrication program.

16.6.1.5 Clearances between moving surfaces that are exposed to paste, powder, or dust shall be maintained to prevent rubbing or jamming.

16.6.1.6 Permanent magnetic separators, pneumatic separators, or screens shall be installed ahead of mills, stamps, or pulverizers wherever there is any possibility that tramp metal or other foreign objects can be introduced into the manufacturing operation.

16.6.1.7 Startup Operations. Before being placed into operation, all areas of processing machinery that will be in contact with combustible metal shall be free of the following:

- (1) Foreign objects and materials
- (2) Water, where combustible metal is reactive with water

16.6.2 Flake and Paste.

16.6.2.1 Machinery and Operations.

16.6.2.1.1* Wet Milling of Metal Powder. The requirements of **16.6.2.1.1.1** through **16.6.2.1.1.6** shall not apply to machining and rolling operations.

16.6.2.1.1.1* Where metal is added to a mill in the presence of a liquid that is chemically inert with respect to the metal, the milling shall be done in air in a vented mill or in an inerting atmosphere containing sufficient oxygen to oxidize any newly exposed surfaces as they are formed.

16.6.2.1.1.2* Where metal is slurried in tanks or processed in blenders or other similar equipment in the presence of a liquid that is chemically inert with respect to the metal, the operation shall be carried out in air or in an inerting atmosphere containing sufficient oxygen to oxidize any newly exposed surfaces as they are formed.

16.6.2.1.1.3 The dew point of the atmospheres in **16.6.2.1.1.1** and **16.6.2.1.1.2** shall be maintained below the point where condensation occurs.

16.6.2.1.1.4 Bearings of wet mills shall be grounded across the lubricating film by use of current collector brushes, a conductive lubricant, or other applicable means.

▲ **16.6.2.1.1.5*** Ventilation in accordance with NFPA 30 shall be maintained in areas where flammable or combustible solvents are handled, particularly in areas where combustible metal dusts or powders are present.

16.6.2.1.1.6 Solvent or slurry pumps shall be installed with controls that ensure that a flow exists and that the pumps run with safe operating temperatures.

16.6.2.2 Electrical Equipment.

16.6.2.2.1 When continuous contact is interrupted, metallic jumpers shall be installed for effective bonding.

▲ **16.6.2.2.2*** Wet solvent milling areas or other areas where combustible or flammable liquids are present shall be classified, where applicable, in accordance with Article 500, 505, or 506 of *NFPA 70* with the exception of control equipment meeting the requirements of NFPA 496.

16.6.3 Plasma Spray Operations.

16.6.3.1 For plasma spray operations, media collectors, if used, shall be located at a distance from the point of collection to eliminate the possibility of hot metal particles igniting the filter media in the collector.

16.6.3.2 Metal overspray temperatures at the dust collector shall be compatible with the limiting temperature of the filter media element.

16.6.4 Transfer Operations.

16.6.4.1* Operations involving the transfer of combustible metal dusts or powders from one container to another shall be designed and operated to protect personnel, equipment, and buildings from the fire or dust explosion hazard produced by airborne suspensions of combustible metal dusts or powders.

16.6.4.2 Prevention of Fugitive Dust Accumulations. See 16.1.2.

▲ **16.6.5 Processing Recycled Material.** The requirements of Chapter 17 shall apply to processes handling recycled metal that is in a combustible form.

16.7* Machining, Fabrication, Finishing, and Media Blasting.

16.7.1 Hot Work Operations.

16.7.1.1 Hot work operations in facilities covered by this standard shall be in accordance with Section 10.2.

16.7.2 General Precautions.

16.7.2.1 Any equipment used for the machining, fabrication, or finishing of metal shall be dedicated to metal only and marked with a placard that reads as follows:

WARNING:

Metal Only — Fire or Explosion Can Result with Other Metals.

16.7.2.2 Equipment producing metal in a combustible form shall be permitted to be used for other materials only when the system is thoroughly cleaned of all incompatible materials prior to and after its use.

16.7.3 Chip Production and Processing.

16.7.3.1 Machining and Sawing Operations.

16.7.3.2 Cutting tools shall be of proper design and shall be kept sharp for satisfactory work with the metal.

16.7.3.3 Sawing, grinding, and cutting equipment shall be grounded.

16.7.3.4 All metal chips, oily crushed lathe turnings, raw turnings, and swarf shall be collected in closed-top containers dedicated to the specific metal only and removed daily, at a minimum, to a safe storage or disposal area.

16.7.3.5 Coolant.

16.7.3.5.1 Nonflammable coolants shall be used for wet grinding, cutting, or sawing operations.

16.7.3.5.2 The coolant shall be filtered on a continuous basis, and the collected solids shall not be allowed to accumulate in quantities greater than 19 L (5 gal) and shall be removed to a safe storage or disposal area.

▲ **16.7.4 Dust Collection.** Dust collection shall be in accordance with Chapter 11.

16.8 Storage and Handling.

16.8.1 Storage of Combustible Metal Powder.

16.8.1.1 Buildings used to store metal powder shall be of noncombustible construction.

16.8.1.2 The use of automatic sprinklers in metal powder storage buildings shall be prohibited.

16.8.1.3 Metal powder shall be kept separated from other ordinary combustibles or incompatible materials.

16.8.1.4 Metal powder shall be stored in closed steel drums or other closed noncombustible containers.

16.8.1.5 Where the metal powder is reactive with water, metal-powder storage areas shall be kept dry.

16.8.1.6* Where metal powder in drums is stacked for storage, the maximum height shall not exceed 3.7 m (12 ft).

16.8.1.6.1 Storage drums shall be stacked in a manner that ensures stability.

16.8.1.6.2 Under no circumstances shall containers be allowed to topple over.

16.8.1.7* Storage of Other Metal Products.

16.8.1.7.1 Storage in quantities greater than 1.4 m³ (50 ft³) shall be separated from storage of other materials that are either combustible or in combustible containers by aisles with a minimum width equal to the height of the piles of metal products.

16.8.1.7.2 Metal products stored in quantities greater than 28 m³ (989 ft³) shall be separated into piles, each not larger than 28 m³ (989 ft³), with the minimum aisle width equal to the height of the piles but not less than 3.1 m (10 ft).

16.8.1.7.3* The storage area shall be protected by automatic sprinklers in any of the following situations:

- (1) Where storage in quantities greater than 28 m³ (989 ft³) is contained in a building of combustible construction
- (2) Where metal products are packed in combustible crates or cartons
- (3) Where other combustible storage is within 9 m (30 ft) of the metal

16.8.2 Scrap Handling, Storage, and Disposal.

16.8.2.1 Storage of Combustible Scrap Metal.

16.8.2.1.1 The requirements of 16.8.2.1 shall apply to the storage of scrap metal in the form of solids, chips, turnings, swarf, or other fine particles.

16.8.2.1.2 Buildings used for the indoor storage of metal scrap shall be of noncombustible construction.

16.8.2.1.3 Scraps shall be kept well separated from other combustible materials.

16.8.2.1.3.1 Scraps shall be kept in covered steel or other noncombustible containers and shall be kept in such manner or locations that they will not become wet.

16.8.2.1.3.2 Outside storage of metal fines shall be permitted if such storage is separated from buildings or personnel and precautions are exercised to prevent the fines from becoming wet.

16.8.2.1.4* Wet metal scrap (chips, fines, swarf, or sludge) shall be kept under water in a covered and vented steel container at an outside location.

16.8.2.1.4.1 Sources of ignition shall be kept away from the container vent and top.

16.8.2.1.4.2 Containers shall not be stacked.

16.8.2.1.5 Storage of dry scrap in quantities greater than 1.4 m³ (50 ft³) [six 208 L drums (six 55 gal drums)] shall be kept separate from other occupancies by fire-resistive construction or by an open space of at least 15 m (50 ft).

16.8.2.1.6 Buildings used for storage of dry scrap shall be well ventilated to avoid the accumulation of hydrogen in the event that the scrap becomes wet.

16.8.2.1.7 Solid metal scrap, such as clippings and castings, shall be stored in noncombustible bins or containers.

16.8.2.1.8 The storage of oily rags, packing materials, and similar combustibles shall be prohibited in storage bins or areas that store solid metal scrap.

16.8.2.1.9 The use of automatic sprinklers in metal-scrap storage buildings or areas shall be prohibited.

16.8.3 Recycling. (Reserved)

16.8.4 Chip Processing. (Reserved)

16.9 Fire and Explosion Prevention.

16.9.1 Fire and explosion prevention shall be in accordance with Chapter 8.

16.9.2 Control of Ignition Sources. (Reserved)

16.9.3 Hot Work Operations. Hot work operations shall be in accordance with Section 10.2.

16.9.4 Control of Combustible Materials. (Reserved)

16.9.5 Inspection, Maintenance, and Training.

Δ 16.9.5.1 Emergency Procedures. Emergency procedures shall be in accordance with Chapter 8.

16.9.5.1.1 Emergency procedures to be followed in case of fire or explosion shall be established.

16.9.5.1.2 All employees shall be trained in the emergency procedures.

16.10 Other. (Reserved)

Chapter 17 Recycling and Waste Management Facilities

17.1* General Provisions.

17.1.1 Retroactivity. The requirements of this chapter shall apply to new and existing recycling and waste management facilities that handle metals in combustible forms, including metal-only mixtures and mixtures containing metals.

Δ 17.1.2 A combustible metal or metal dust hazard shall be identified by testing in accordance with Chapters 4 and 5 prior to application of any of the provisions of this chapter.

Δ 17.1.3 For facilities recycling or providing treatment or disposal services, the requirements of Chapters 6 through 10 shall also apply.

17.2 Recycling and Waste Management of Combustible Metal — Collection, Storage, and Handling of Fines Generated During Scrap Receiving, Storage, Recycling, and Waste Treatment.

17.2.1 Receiving Criteria. Incoming material shall be inspected for acceptance criteria.

17.2.1.1 Acceptance criteria for combustible metals being recycled shall be established by the recycler. The acceptance criteria shall include the following as a minimum:

- (1) Acceptable packaging
- (2) Forms
- (3) Identification/manifest (DOT shipping papers)
- (4) Required protection against foreign material
- (5) Identification and segregation of any radiation/contamination of materials
- (6) SDS
- (7) Certificate of insurance
- (8) Authorized signature of acceptance of material
- (9) Internal quality control procedures
- (10) Incoming material analysis plan
- (11) Nonconforming material plan

17.2.1.2 Acceptance criteria for combustible metals offered for waste disposal shall be established by communication between the generator and waste disposal facility and shall include the following as a minimum:

- (1) Acceptable packaging
- (2) Waste profile specifying the form of the material and any changes in form or concentration from previous shipments
- (3) Waste analysis plan
- (4) Identification and concentration range of constituents
- (5) Required protection against physical hazards including combustibility, pyrophoric, and water reactivity
- (6) Identification and segregation from incompatible materials if stored
- (7) SDS
- (8) Nonconforming material plan

17.2.1.3 The acceptance criteria shall be documented and available for review by the AHJ.

17.2.2 Rejected Material.

17.2.2.1 Combustible metal only and mixtures containing combustible metals that cannot be stored, handled, or processed by the receiving facility shall be rejected

17.2.2.2 Rejected material shall be returned to the supplier within 5 working days or days or engineering controls, or alternate methods for the safe disposal of the rejected material shall be implemented in accordance with local, state, and federal regulations.

17.2.2.3 Rejected material shall be labeled and segregated in an area identified for storage of rejected or nonconforming material in accordance with the nonconforming materials plan.

17.3 Storage of Combustible Metals for Recycling and Waste Management.

17.3.1 Combustible metal-only mixtures, mixtures containing combustible metals, and materials that can potentially produce combustible metal or metal dust as a result of normal handling shall include provisions for the handling of any possible resulting metals as defined in this section.

17.3.2* Containers and areas where combustible metals are stored shall be labeled or identified as to the type of metal stored, form of metal, and date of receipt.

17.3.3 A tracking system shall be implemented for inventory control and shall include the following:

- (1) Type and form of combustible metal
- (2) Storage location
- (3) Date of receipt
- (4) Other hazards including but not limited to reactivity with water, pyrophoric, and compatibility

17.3.4 The tracking records shall be available for inspection by the authority having jurisdiction.

17.3.5 Area and container labels or identification shall reference the appropriate material safety data sheets (MSDSs) on file.

17.3.6 Buildings used for the indoor storage of combustible metal shall be of noncombustible construction and shall meet the requirements of 16.2.1.

17.3.7 Solid combustible metals, such as clippings and castings, shall be stored in noncombustible bins or containers.

17.3.8 Combustible metals shall be separated from other combustible materials that would provide additional fuel in the event of a fire such as wood pallets and corrugated cardboard.

17.3.9 The storage of oily rags, packing materials, and similar combustibles shall be prohibited in storage bins or areas that store solid recycled combustible metal.

17.3.10* Combustible metals delivered for recycling or waste disposal that are stored on-site shall be identified as wet or dry.

17.3.11 Dry Combustible Metals Storage. Combustible metals in a dry condition shall be kept in covered steel or other noncombustible containers and shall be kept in such manner or locations that they will not become wet.

17.3.11.1 Buildings used for storage of dry combustible metal shall be well ventilated to avoid the accumulation of hydrogen in the event that the combustible metal becomes wet.

17.3.11.2 When the recyclable or waste material has the potential for water reactivity because of the specific combustible metal content, provisions shall be made to keep it dry.

17.3.11.3 Outside storage of dry combustible metals shall be permitted if such storage is separated from buildings or personnel.

17.3.11.4 Storage of dry combustible metals in quantities greater than 1.4 m³ (50 ft³) [six 208 L drums (six 55 gal drums)] shall be kept separate from other occupancies by fire-resistant construction or by an open space of at least 15 m (50 ft).

17.3.11.5 Quantity Separation Distance. (Reserved)

17.3.12 Wet Combustible Metals Storage.

17.3.12.1 Wet combustible metals shall be stored at an outside location identified for that use.

17.3.12.2 Open flames and sparks shall be kept 15 m (50 ft) away from the container unless a hot-work permit allows an open flame within 15 m (50 ft).

17.3.12.3* Combustible metals that are received wet shall be kept under water in a covered and vented container.

17.3.12.4 Containers of wet combustible metals shall not be stacked.

17.3.12.5 Quantity Separation Distance. (Reserved)

17.3.13 Container Limits.

17.3.13.1 Where drums or other containers are used for storage of dry combustible metals, storage shall be limited to a height that would require no more than three movements using available equipment to remove a stack, and no stack shall exceed 3.1 m (10 ft) in height.

17.3.13.2 The maximum weight of any material container and/or pallet shall be capable of being moved by the available equipment.

17.3.13.3 Stacked storage shall be arranged to ensure stability.

17.3.13.3.1 Aisles shall be provided for maneuverability of material handling equipment, for accessibility, and to facilitate fire-fighting operations

17.4 Sample Identification and Collection for Metals in a Combustible Form.

▲ **17.4.1** When the combustibility of a metal or mixture is not known or reported on the waste manifest sheet, the metal shall be tested as specified in Chapter 5 to determine whether it is a combustible metal.

17.4.2 For waste disposal, the waste manifest shall disclose the type of metal(s) by name and if they are in a combustible form.

17.4.3* In recycling facilities where combustible metals are processed, samples shall be collected that represent a "worst case" scenario.

▲ **17.4.4** Each site shall develop a sampling strategy and protocol to ensure that samples are collected in all areas where combustible metals and metal dust can reasonably be assumed to be present. The following shall be considered in developing the sampling strategy:

- (1) All processes that produce dust (e.g., UBC processing; remelt and casting; alloying molten metal; aluminum scrap chopping, conveyance, shredding, handling, and sawing; etc.)

- (2) Horizontal surfaces on and around the process identified.
- (3) Various heights on the equipment and in the building.
Note: lighter, small particle-sized dust tends to collect higher in the structure.
- (4) Recessed or hidden areas where dust could have collected.
- (5) Worst-case process situations where possible. For example, higher magnesium content has been shown to have higher energy potential.
- (6) Inside bins, hoppers, baghouses, cyclones, ductwork, etc., used to store, collect, and convey materials.

17.4.5 Samples collected shall be promptly submitted for testing as dust tends to oxidize over time.

17.5 Personal Protective Equipment (PPE). PPE shall be in accordance with Section 4.6.

17.6 Reactivity.

17.6.1 It shall be the responsibility of the recycling and waste management facilities to evaluate processes and materials for potentially dangerous reactions that could occur in the course of their operations.

17.6.2 Contact with Water.

17.6.2.1* Water leakage inside or into any building where the water can contact metal-reactive materials shall be prevented to avoid possible spontaneous heating.

17.6.3 Thermite Reaction.

17.6.3.1* Caution shall be exercised in the mixing of metal fines and metal oxides [e.g., iron oxide (rust)].

17.7 Management of Change. Management of change shall be in accordance with Section 4.4.

17.8 Facility Design Requirements.

17.8.1 Building Construction.

17.8.1.1 Location of Recycling and Waste Management Facilities.

17.8.1.1.1 A hazards analysis shall be conducted to determine the minimum separation distance for individual buildings and operations within recycling and waste management plants.

17.8.1.2 All buildings used for the processing, packing, or loading for shipment of recyclable materials shall be constructed of noncombustible materials throughout and shall have non-load bearing walls.

17.8.1.3 Where dust is present, the buildings specified in 17.8.1.2 shall be designed so that all internal surfaces are readily accessible, to facilitate cleaning.

17.8.1.4 Where dust is present, all walls of areas where fugitive dust can be produced shall have a smooth finish and shall be sealed so as to leave no interior or exterior voids where combustible metal dust can infiltrate and accumulate.

17.8.1.5 The annuli of all pipe, conduit, and ventilation penetrations shall be sealed.

17.8.1.6 Floors shall be hard surfaced and shall be installed with a minimum number of joints in which metal dust can collect.

17.8.1.7 The requirements of 17.8.1.4 shall also apply to elevated platforms, balconies, floors, and gratings.

17.8.1.8 Roofs of buildings that house combustible metal dust-producing operations shall be supported on girders or structural members designed to minimize surfaces on which dust can collect.

17.8.1.9* Interior surfaces where combustible metal dust accumulations can occur shall be designed and constructed to facilitate cleaning and to minimize combustible dust accumulations.

17.8.1.10 Where surfaces on which combustible metal dust can collect are unavoidably present, they shall be covered by a smooth concrete, plaster, or noncombustible mastic fillet having a minimum slope of 55 degrees to the horizontal.

17.8.1.11 Roof decks and basements shall be watertight.

▲ **17.8.1.12** Explosion venting in accordance with NFPA 68 shall be provided for buildings where metal powders are processed.

17.8.1.13 Deflagration venting shall not be required for areas where combustible metals are stored or moved only in covered or sealed containers.

17.8.1.14 Door and Window Construction.

▲ **17.8.1.14.1** All doors in interior fire-rated partitions shall be listed self-closing fire doors, installed in accordance with NFPA 80.

▲ **17.8.1.14.2*** Emergency exits shall be provided in compliance with NFPA 101.

17.8.1.15 Enclosed Passageways.

▲ **17.8.1.15.1** Where buildings or process areas are interconnected by enclosed passageways, the passageways shall be designed to prevent propagation of an explosion or fire from one unit to another in accordance with NFPA 68.

▲ **17.8.1.15.2** All enclosed passageways that connect with one or more processing areas shall be provided with means of egress in accordance with NFPA 101.

17.8.1.16 Grounding and Lightning Protection.

▲ **17.8.1.16.1*** All process equipment and all building steel shall be bonded and grounded in accordance with NFPA 70.

▲ **17.8.1.16.2** All buildings shall be provided with a lightning protection system in accordance with NFPA 780.

17.8.1.16.3 Lightning protection systems shall not be required for office buildings and buildings that are used for storage and handling of closed containers.

17.8.1.17 Heating and Cooling of Production Buildings.

17.8.1.17.1 Buildings shall be permitted to be heated by indirect hot-air heating systems or by bare-pipe heating systems using steam or hot water as the heat transfer medium, or by listed electric heaters.

17.8.1.17.2 Indirect hot air shall be permitted if the heating unit is located in an adjacent room or area that is free of combustible dust.

17.8.1.17.3 Fans or blowers used to convey heated or cooled air shall be located in an area that is free of combustible dust.

17.8.1.17.4 The air supply shall be taken from outside or from a location that is free of combustible dust.

17.8.1.17.5 Makeup air for building heating or cooling shall have a dew point low enough to ensure that no free moisture can condense at any point where the air is in contact with combustible metal dust or powder.

17.8.1.17.6 The requirements of **17.8.1.17.1** through **17.8.1.17.5** shall not apply to areas where combustible metal is melted.

17.8.2 Fire Protection.

▲ **17.8.2.1** Fire protection shall be in accordance with Chapter 8.

17.8.3 Electrical Classification.

17.8.3.1 Electrical classification shall be in accordance with Section 10.8.

17.8.4 Hazard Analysis. Hazard analysis shall be in accordance with Section 4.5.

17.9 Emergency Preparedness.

17.9.1 Procedures.

17.9.1.1 Emergency procedures shall be established to address fire and explosion events in accordance with Sections 8.5 and 8.4.

17.9.1.2 The emergency procedures shall be documented.

17.9.1.3 In cases where a process hazard analysis indicates that application of low-velocity water can be beneficial for the preservation of life and/or property, the provisions of 8.3.3.5 shall be superseded.

17.9.1.3.1 If the determination is made to apply low-velocity water to a fire, the following shall be observed:

- (1) Care is to be taken to prevent the formation of a dust cloud.
- (2) The area is to be determined to be well ventilated, and/or ventilation should be maximized prior to water application, in order to prevent to the accumulation of hydrogen gas.
- (3) After extinguishment, the area is to be cleaned of all wetted powder, paste, or slurry, and ventilation should be continued throughout this process.

17.9.2* Training.

17.9.2.1 All employees shall be trained in the emergency procedures and the hazards of combustible metals.

17.9.2.2 Training shall be documented and available for inspection by the authority having jurisdiction.

17.10 Processing.

▲ **17.10.1** Control of ignition sources shall be in accordance with Chapter 8.

17.10.1.1 Recyclers and waste generators or waste brokers shall determine the combustibility and explosivity characteristics of any waste, by-product, intermediate, or final material generated as a result of on-site processing.

17.10.1.2* Documentation of the determination in **17.10.1.1** shall be maintained and available for review by the authority having jurisdiction.

▲ **17.10.1.3** For all processing of recycled combustible metals for which there are specific chapters, the requirements of those chapters shall apply in addition to the requirements of Chapter 17.

▲ **17.10.1.4** For all other recycled combustible metal and alloy processing, the requirements of Chapter 16 shall also apply.

▲ **17.10.1.5** Combustible or flammable liquids resulting from recycling of combustible metals shall be handled and stored in accordance with NFPA 30.

▲ **17.10.1.6** Hazardous materials resulting from recycling of combustible metals shall be handled and stored in accordance with local, state, and federal regulations and NFPA 1.

17.10.1.7 Sumps and trenches in manufacturing and process areas should be cleaned at the end of the work shift to prevent accumulation of fines and incompatible materials.

17.10.2 Machining and Operations.

17.10.2.1 Requirements for Machinery.

17.10.2.2 All combustible metal dust-producing machines and conveyors shall be designed, constructed, and operated so that fugitive dust is minimized.

▲ **17.10.2.3** All machinery and equipment shall be installed in accordance with NFPA 70.

17.10.2.4* All machinery shall be bonded and grounded to minimize accumulation of static electric charge.

17.10.2.5 Bearings.

17.10.2.5.1* Ball or roller bearings shall be sealed against dust.

17.10.2.5.2 Where exposed bearings are used, the bearings shall be protected to prevent ingress of combustible metal and metal dust and shall have a lubrication program.

17.10.2.5.3 Clearances between moving surfaces that are exposed to paste, powder, or dust shall be maintained to prevent rubbing or jamming.

17.10.2.5.4 Permanent magnetic separators, pneumatic separators, or screens shall be installed ahead of mills, stamps, or pulverizers wherever there is any possibility that tramp metal or other foreign objects can be introduced into processing related operations.

17.10.2.5.5 All areas of processing machinery that will be in contact with combustible metal materials shall be free of foreign objects, foreign material, and water before being placed in operation.

17.10.3 Transfer Operations.

17.10.3.1* Operations involving the transfer of combustible metals or metal dusts or powders from one container to another shall be designed and operated to protect personnel, equipment, and buildings from the fire or dust explosion hazard produced by airborne suspensions of metals in a combustible form.

17.10.3.2 The container shall be grounded and bonded and nonsparking tools shall be used.

17.10.3.3 Equipment producing metal in a combustible form shall be permitted to be used for other materials only when the system is thoroughly cleaned of all incompatible materials prior to and after its use.

17.10.4 Electrical Equipment.

- Δ **17.10.4.1** All electrical wiring and equipment shall be in accordance with Chapter 10.

17.10.5 Chip Processing. (Reserved)

17.10.6 Machining and Sawing Operations.

17.10.6.1* Cutting tools shall be of proper design and shall be kept sharp for satisfactory work with the metal being processed.

17.10.6.2* Sawing, grinding, and cutting equipment shall be grounded.

17.10.7 Coolant.

17.10.7.1 Nonflammable coolants shall be used for wet grinding, cutting, or sawing operations.

17.10.7.2 The coolant shall be filtered on a continuous basis, and the collected solids shall not be allowed to accumulate in quantities greater than 19 L (5 gal) and shall be removed to a safe storage or disposal area.

17.10.8 Dust Collection.

- Δ **17.10.8.1** Dust collection shall be in accordance with Chapter 11.

17.11 Fire and Explosion Prevention.

- Δ **17.11.1** The requirements of Chapter 8 shall apply.

17.11.2 Housekeeping.

- Δ **17.11.2.1** The requirements of Chapter 9 shall apply.

17.11.3 Control of Metals in a Combustible from Finishing Operations.

17.11.3.1 It shall be permissible to use an open top container to collect metal chips, lathe turnings, and swarf if the container is grounded and has shelter to prevent water entrainment.

17.11.3.2 If the containers collecting metal chips, lathe turnings, and swarf are to be sent for disposal, the specific metal and form of the waste shall be documented.

17.11.4 Inspection, Maintenance, and Training.

17.11.4.1 Regular inspections shall be conducted to detect the accumulation of excessive metals in a combustible form on any portions of buildings or machinery not regularly cleaned in daily operations.

17.11.4.2 Records shall be kept of the inspections conducted in 17.11.4.

Annex A Explanatory Material

Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.1.1 Under proper conditions, most metals in the elemental form will react with oxygen to form an oxide. These reactions are exothermic. The conditions of the exposure are affected by the temperature of the metal (whether it is in large pieces or in the form of small particles), the ratio of its surface area to its total weight, the extent or presence of an oxide coating, the temperature of the surrounding atmosphere, the oxygen content of the atmosphere, the moisture content of the atmosphere, and the presence of flammable vapors.

A.1.1.1 Any metal in a fine enough form can be combustible and/or explosible.

- **A.1.1.2.2** Ignitable fibers/flyings, as defined in NFPA 70 and NFPA 499, do not present a flash-fire hazard or explosion hazard and are not included in the definition of combustible dust in this standard. Ignitable fibers/flyings present a fire hazard, so locations are classified differently and the electrical installation includes additional restrictions compared to combustible fibers/flyings. Ignitable metal fibers/flyings would be anticipated to be identified as a combustible metal in accordance with Chapter 5.

A.1.1.3 Products or materials that have the characteristics of a combustible metal should have a safety data sheet (SDS) that describes those burning characteristics. The manufacturer or technical personnel with knowledge of the hazards associated with the metal should be consulted to characterize the hazards of the metal. [See Table A.1.1.3(a) and Table A.1.1.3(b).]

- Δ **A.1.1.6** The number of mixtures containing metals is infinite. Mixtures could contain one or more of the following materials in any range of concentration: metals, metal oxides, inorganic compounds, organic compounds, oxidizers, flammable liquids, combustible liquids, water, and water-based solutions. Consequently, the mixture could exhibit a range of hazards from none to more than one physical hazard based on content, composition, form, and moisture content. In some cases, a mixture can be more hazardous than the individual metal(s); for example, pyrotechnics. A representative sample of a mixture containing one or more metals requires characterization and testing. Characterization includes a breakdown of the constituents, form(s), particle size and distribution where applicable, moisture content where applicable, and propensity to separate. If the composition or particle size of the mixture changes, a new representative sample should be collected and evaluated.

While NFPA 484 might not be applicable to a particular mixture, the mixture could be included in the scope of other NFPA standards including, but not limited to, NFPA 61, NFPA 120, NFPA 495, NFPA 654, and NFPA 655.

- Δ **A.1.1.6.2** Metal-containing mixtures where the primary hazard is from combustible metals and the mixture behaves as a metal are covered by NFPA 484. Mixtures where the primary hazard is from nonmetals and the mixture behaves as a nonmetal might be covered by other commodity-specific standards. The criteria in 1.1.6.2(1), 1.1.6.2(2), and 1.1.6.2(3) determine whether the mixture can be extinguished using conventional fire-fighting measures commonly prescribed in other standards. See 8.3.3.1.1

Table A.1.1.3(a) Metal Properties — Key Temperatures

Metal	Melting Point (°C)	Boiling Point (°C)	Solid Metal Ignition (°C)	Max. Adiabatic Flame Temperature* (°C)
Aluminum	660	2452	555	3790
Barium	725	1140	175	—
Boron	2300	2550		3030
Calcium	824	1440	704	—
Chromium	1857	2672		2900
Copper	1085	2567		1250
Hafnium	2223	5399		4580
Iron	1535	3000	930	2220
Lithium	186	1336	180	—
Magnesium	650	1110	623	3340
Manganese	1246	1962		—
Molybdenum	2617	4612		2390
Nickel	1453	2732		2130
Niobium	2468	4927		3270
Plutonium	640	3315	600	—
Potassium	62	760	69	—
Silicon	1410	2355		2970
Sodium	98	880	115	—
Strontium	774	1150	720	1980
Tantalum	2996	5425	—	3490
Thorium	1845	4500	500	—
Titanium	1727	3260	1593	3720
Tungsten	3422	5660		2830
Uranium	1132	3815	3815	—
Zinc	419	907	900	1800
Zirconium	1830	3577	1400	4690 [†]

*Maximum adiabatic flame temperature calculations from Cashdollar and Zlochower, *J. Loss Prevention*, vol. 20, 2007.

[†]Adiabatic flame temperature for zirconium from National Energy Technology Laboratory (NETL), Albany, OR.

for additional information on the criteria in 1.1.6.2(1) and 1.1.6.2(2). List item 1.1.6.2(4) examines the volume resistivity of the mixture. NFPA 77 defines conductive solids as having a resistivity less than 10^5 ohm-m. This requirement provides a factor of ten increase reflective of some quantity of lower resistivity material in the mixture. Metal mixtures present additional ignition hazards associated with conductivity, such as arcing at electrical contacts and a propensity for static discharges. List item 1.1.6.2(5) addresses thermite reactions, which are not covered by other standards.

Additional analysis such as differential scanning calorimetry (DSC) and thermal gravimetric analysis (TGA) in air might be warranted to determine if the primary hazards of a mixture are due to combustion of metals or combustion of nonmetals in the mixture.

Since there is often a wide variety of mixture compositions in a facility, mixture composition variations should be documented, and the selection of the particular mixture sample submitted for testing should be described with the basis of selection included. If the mixture is combustible and is to be excluded from this standard, either NFPA 654 or some other combustible dust standard should be used to establish suitable fire and explosion protection measures. For additional guidance on

water reactivity tests, see Janés, A., *Journal of Loss Prevention in the Process Industries*.

A.1.1.7 Regulations for the domestic shipment of dangerous goods (lithium and lithium alloy materials are so classified) are issued by the Department of Transportation (DOT), 49 CFR 100–199, which has specific responsibility for promulgating the regulations. These regulations are updated and published yearly by DOT.

International shipments are regulated by the United Nations, International Air Transport Association, International Maritime Organization, and other national agencies.

Δ A.1.1.11 A combustible metal is a metal that meets the criteria for combustibility as defined in Chapter 5. The quantities listed in Table 1.1.11 are for the entire occupancy, not for individual fire control areas.

Δ A.1.5.2 The requirements identified in Chapter 8 and Chapter 17 are applicable to new and existing facilities.

N A.1.6.2 A given equivalent value could be an approximation.

A.3.2.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase “authority having jurisdiction,” or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.3.2.4 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

N A.3.3.1 Air-Material Separator (AMS). Examples include cyclones, bag filter houses, dust collectors, and electrostatic precipitators. [652, 2019]

Table A.1.1.3(b) Explosibility Properties of Metals

Material	Median Diameter (µm)	K_{st} (bar-m/s)	P_{max} (bar g)	Cloud Ign Temp (°C)	MIE (mJ)	MEC (g/m ³)	VDI Combustibility Class ²	LOC ¹ (v%)	Data Source
Aluminum	~7	—	8	—	—	90			Cashdollar & Zlochower ⁴
Aluminum	22	—	—	—	—	—	—	5 (N)	BGIA ³
Aluminum	<44	—	5.8	650	50	45	—	2 (C)	BuMines RI 6516
Aluminum flake	<44	—	6.1	650	20	45	—	<3 (C)	BuMines RI 6516
Aluminum	<10	515	11.2	560	—	60	—	—	BGIA ³
Aluminum	580	Not ignited	—	—	—	—	—	—	BGIA
Beryllium	4	Not ignited	—	—	—	—	—	—	BuMines RI 6516
Boron	<44	—	—	470	60	<100	—	—	BuMines RI 6516
Boron	~3	—	6.0	—	—	≈110	—	—	Cashdollar & Zlochower
Bronze	18	31	4.1	390	—	750	BZ 4	—	Eckhoff
Chromium	6	—	3.3	660	5120	770	—	14 (C)	BuMines RI 6516
Chromium	3	—	3.9	580	140	230	—	—	BuMines RI 6517
Copper	~30	Not ignited	—	—	—	—	—	—	Cashdollar & Zlochower
Hafnium	~8	—	4.2	—	—	~180	—	—	Cashdollar & Zlochower
Iron	12	50	5.2	580	—	500	—	—	Eckhoff
Iron	~45	—	2.1	—	—	~500	—	—	Cashdollar & Zlochower
Iron	<44	—	2.8	430	80	170	—	13 (C)	BuMines RI 6516
Iron, carbonyl	<10	111	6.1	310	—	125	BZ 3	—	Eckhoff
Manganese	<44	—	—	460	305	125	—	—	BuMines RI 6516
Manganese (electrolytic)	16	157	6.3	330	—	—	—	—	Eckhoff
Manganese (electrolytic)	33	69	6.6	—	—	—	—	—	Eckhoff
Magnesium	28	508	17.5	—	—	—	—	—	Eckhoff
Magnesium	240	12	7	760	—	500	BZ 5	—	Eckhoff
Magnesium	<44	—	—	620	40	40	—	—	BuMines RI 6516
Magnesium	<44	—	—	600	240	30	—	<3 (C)	BuMines RI 6516
Magnesium	~16	—	7.5	—	—	55	—	—	Cashdollar & Zlochower
Molybdenum	<10	Not ignited	—	—	—	—	—	—	Eckhoff
Nickel	~6	Not ignited	—	—	—	—	—	—	Cashdollar & Zlochower
Niobium	80	238	6.3	560	3	70	—	6 (Ar)	Industry
Niobium	70	326	7.1	591	3	50	—	5 (Ar)	Industry
Silicon	<10	126	10.2	>850	54	125	BZ 3	—	Eckhoff
Silicon, from dust collector	16	100	9.4	800	—	60	—	—	Eckhoff
Silicon, from filter	<10	116	9.5	>850	250	60	BZ 1	—	Eckhoff
Tantalum	<44	—	—	630	120	<200	—	3 (Ar)	BuMines RI 6516
Tantalum	~10	—	≈3	—	—	≈400	—	—	Cashdollar & Zlochower
Tantalum	100	149	6.0	460	<3	160	—	2 (Ar)	Industry
Tantalum	80	97	3.7	540	<3	160	—	2 (Ar)	Industry
Tantalum	50	108	5.5	520	<3	160	—	2 (Ar)	Industry
Tantalum	65	129	5.8	460	<3	160	—	2 (Ar)	Industry
Tantalum	21	—	5.6	430	<3	125	—	<2 (Ar)	Industry
Tantalum	25	—	—	400	1–3	30	—	<2 (Ar)	Industry
Tin	~8	—	3.3	—	—	~450	—	—	Cashdollar & Zlochower
Titanium	36	Not ignited	—	—	—	—	BZ 2	—	BGIA
Titanium	30	—	—	450	—	—	—	—	Eckhoff
Titanium	~25	—	4.7	—	—	70	—	—	Cashdollar & Zlochower
Titanium	10	—	4.8	330	25	45	—	6 (N) 4 (Ar)	BuMines RI 6516
Tungsten	≤1	—	~2.3	—	—	~700	—	—	Cashdollar & Zlochower
Tungsten	~10	Not ignited	—	—	—	—	—	—	Cashdollar & Zlochower

(continues)

Table A.1.1.3(b) Continued

Material	Median Diameter (µm)	K_{St} (bar-m/s)	P_{max} (bar g)	Cloud Ign Temp (°C)	MIE (mJ)	MEC (g/m ³)	VDI Combustibility Class ²	LOC ¹ (v%)	Data Source
Zinc (from collector)	<10	125	6.7	570	—	250	BZ 3		Eckhoff
Zinc (from collector)	10	176	7.3	—	—	125	BZ 2		Eckhoff
Zinc (from Zn coating)	19	85	6	800	—	—	BZ 2		Eckhoff
Zinc (from Zn coating)	21	93	6.8	790	—	250	—		Eckhoff
Zirconium	<44	—	5.2	20	5	45	—	Ignites in N ₂ & CO ₂	BuMines RI 6516
Zirconium (Zircalloy-2)	50	—	3.0	420	30	—	—	—	BuMines RI 6516

1. Limiting Oxygen Concentration. The letter in parenthesis in the LOC column denotes the inert gas used to reduce the oxygen concentration as follows: Ar = argon, C = carbon dioxide, N = nitrogen.

2. VDI Guidelines 2263, Part 1, *Test Methods for the Determinations of Safety Characteristics Dusts*, classes are as follows:

- BZ1 No self-sustained combustion
- BZ2 Local combustion of short duration
- BZ3 Local sustained combustion, but no propagation
- BZ4 Propagating smoldering combustion
- BZ5 Propagating open flame
- BZ6 Explosive combustion

3. BGIA is the GESTIS-DUST-EX database maintained by BGIA.

4. Cashdollar, K., and I. Zlochower, "Explosion Temperatures and Pressures of Metals and Other Elemental Dust Clouds," *J. Loss Prevention in the Process Industries*, vol. 20, 2007.

A.3.3.2 Air-Moving Device (AMD).

- (1) Fans
 - (a) A wide range of devices that utilize an impeller, contained within a housing, that when rotated create air/gas flow by negative (vacuum) or positive differential pressure.
 - (b) These devices are commonly used to create comparatively high air/gas flows at relatively low differential pressures.
 - (c) These devices are typically used with ventilation and/or dust collection systems.
 - (d) Examples are centrifugal fans, industrial fans, mix or axial flow fans, and inline fans.
- (2) Blowers
 - (a) A wide range of devices that utilize various shaped rotating configurations, contained within a housing, that when rotated create air/gas flow by negative (vacuum) or positive differential pressure.
 - (b) These devices are commonly used to create comparatively high differential pressures at comparatively low air/gas flows.
 - (c) The most common use of these devices is with pneumatic transfer, high-velocity, low-volume (HVLV) dust collection and vacuum cleaning systems.
 - (d) Examples are positive displacement (PD) blowers, screw compressors, multistage centrifugal compressors/blowers and regenerative blowers.

[652, 2019]

A.3.3.7.1 Heavy Casting. Castings less than 11.3 kg (25 lb) are considered light castings.

A.3.3.8 Centralized Vacuum Cleaning System. This system normally consists of multiple hose connection stations hard-piped to an AMS located out of the occupancy area. Positive displacement or centrifugal AMDs can be used to provide the

negative pressure airflow. The hoses and vacuum cleaning tools used with the system should be designed to be conductive or static-dissipative to minimize any risk of generating an ignition source. Low minimum ignition energy (MIE) materials (e.g., many powder or dust form metals) should be given special considerations in the system design and use. A primary and secondary AMS separator combination (e.g., cyclone and filter receiver or wet separator) can be used if large quantities of materials are involved. However, most filter receivers or wet separators are capable of handling the high material loadings without the use of a cyclone.

A.3.3.9 Chips. Chips vary in ease of ignition and rapidity of burning, depending on their size and geometry. A light, fluffy chip can ignite easily and burn vigorously, whereas a heavy, compact chip ignites with difficulty and burns quite slowly.

A.3.3.10 Combustible Dust. The term *combustible dust* when used in this standard includes powders, fines, fibers, flyings, etc. Combustible fibers/flyings are specifically mentioned because, while the hazard is the same, *NFPA 70* and *NFPA 499* treat combustible dust and combustible fibers/flyings separately in regards to establishing hazardous (classified) locations and specifying the electrical installation. Ignitable fibers/flyings, as defined in *NFPA 70* and *NFPA 499*, do not present a flash-fire or explosion hazard and are not included in the definition of combustible dust in this standard. Ignitable fibers/flyings present a fire hazard, so locations are classified differently and the electrical installation includes additional restrictions compared to combustible fibers/flyings. [652, 2019]

This definition also includes consideration of a process-specific oxidizing medium other than air. A larger particle size material might not present a hazard in air, yet could present a hazard in an atmosphere with increased oxygen concentration. Similarly, a combustible metal might still present a hazard in an atmosphere typically considered inert, such as CO₂ or nitrogen. [652, 2019]

Dusts traditionally were defined as material 420 μm or smaller (i.e., capable of passing through a U.S. No. 40 standard sieve). For consistency with other standards, 500 μm (i.e., capable of passing through a U.S. No. 35 standard sieve) is now considered an appropriate size criterion. Particle surface area-to-volume ratio is a key factor in determining the rate of combustion. Combustible particulate solids with the smallest dimension more than 500 μm generally have a surface-to-volume ratio that is too small to pose a deflagration hazard. Fibers/flyings with lengths that are large compared to their diameter or thickness usually do not pass through a 500 μm sieve, yet could still pose a deflagration hazard. Many particulates accumulate electrostatic charge in handling, causing them to attract each other, forming agglomerates. Often, agglomerates behave as if they were larger particles, yet when they are dispersed they present a significant hazard. Therefore, it can be inferred that any particulate that has the smallest dimension less than or equal to 500 μm could behave as a combustible dust if suspended in air or the process-specific oxidizer. If the smallest dimension of the particulate is greater than 500 μm , it is unlikely that the material would be a combustible dust, as determined by test. The determination of whether a sample of combustible material presents a flash-fire or explosion hazard could be based on a screening test methodology such as provided in ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*. Alternatively, a standardized test method such as ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, could be used to determine dust explosibility. Chapter 5 of NFPA 652 has additional information on testing requirements. [652, 2019]

There is some possibility that a sample will result in a false positive in the 20 L sphere when tested by the ASTM E1226 screening test or the ASTM E1515 test. This is due to the high energy ignition source overdriving the test. When the lowest ignition energy allowed by either method still results in a positive result, the owner/operator can elect to determine whether the sample is a combustible dust with screening tests performed in a larger scale ($\geq 1 \text{ m}^3$) enclosure, which is less susceptible to overdriving and thus will provide more realistic results. [652, 2019]

This possibility for false positives has been known for quite some time and is attributed to “overdriven” conditions that exist in the 20 L chamber due to the use of strong pyrotechnic igniters. For that reason, the reference method for explosibility testing is based on a 1 m^3 chamber, and the 20 L chamber test method is calibrated to produce results comparable to those from the 1 m^3 chamber for most dusts. In fact, the U.S. standard for 20 L testing (ASTM E1226) states, “The objective of this test method is to develop data that can be correlated to those from the 1 m^3 chamber (described in ISO 6184-1 and VDI 3673).” ASTM E1226 further states, “Because a number of factors (concentration, uniformity of dispersion, turbulence of ignition, sample age, etc.) can affect the test results, the test vessel to be used for routine work must be standardized using dust samples whose K_{St} and P_{max} parameters are known in the 1 m^3 chamber.” [652, 2019]

NFPA 68 also recognizes this problem and addresses it stating that “the 20 L test apparatus is designed to simulate results of the 1 m^3 chamber; however, the igniter discharge makes it problematic to determine K_{St} values less than 50 bar-m/sec. Where the material is expected to yield K_{St} values less than 50 bar-m/sec, testing in a 1 m^3 chamber might yield lower values.” Any time a combustible dust is processed or handled, a

potential for deflagration exists. The degree of deflagration hazard varies, depending on the type of combustible dust and the processing methods used. [652, 2019]

A dust deflagration has the following four requirements:

- (1) Combustible dust
 - (2) Dust dispersion in air or other oxidant
 - (3) Sufficient concentration at or exceeding the minimum explosible concentration (MEC)
 - (4) Sufficiently powerful ignition source such as an electrostatic discharge, an electric current arc, a glowing ember, a hot surface, welding slag, frictional heat, or a flame
- [652, 2019]

If the deflagration is confined and produces a pressure sufficient to rupture the confining enclosure, the event is, by definition, an “explosion.” [652, 2019]

Evaluation of the hazard of a combustible dust should be determined by the means of actual test data. Each situation should be evaluated and applicable tests selected. The following list represents the factors that are sometimes used in determining the deflagration hazard of a dust:

- (1) MEC
 - (2) MIE
 - (3) Particle size distribution
 - (4) Moisture content as received and as tested
 - (5) Maximum explosion pressure at optimum concentration
 - (6) Maximum rate of pressure rise at optimum concentration
 - (7) K_{St} (normalized rate of pressure rise) as defined in ASTM E1226
 - (8) Layer ignition temperature
 - (9) Dust cloud ignition temperature
 - (10) Limiting oxidant concentration (LOC) to prevent ignition
 - (11) Electrical volume resistivity
 - (12) Charge relaxation time
 - (13) Chargeability
- [652, 2019]

It is important to keep in mind that as a particulate is processed, handled, or transported, the particle size generally decreases due to particle attrition. Therefore, it is often necessary to evaluate the explosibility of the particulate at multiple points along the process. Where process conditions dictate the use of oxidizing media other than air, which is nominally taken as 21 percent oxygen and 79 percent nitrogen, the applicable tests should be conducted in the appropriate process-specific medium. [652, 2019]

N A.3.3.11 Combustible Fibers/Flyings. Section 500.5 of NFPA 70 defines a Class III location. Combustible fibers/flyings can be similar in physical form to ignitable fibers/flyings and protected using the same electrical equipment installation methods. Examples of fibers/flyings include flat platelet-shaped particulate, such as metal flake, and fibrous particulate, such as particle board core material. If the smallest dimension of a combustible material is greater than 500 μm , it is unlikely that the material would be combustible fibers/flyings, as determined by test. Finely divided solids with lengths that are large compared to their diameter or thickness usually do not pass through a 500 μm sieve, yet when tested could potentially be determined to be explosible. [499, 2021]

The typical test methods for evaluating an explosible mixture are ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, ISO 6184-1, *Explosion protection systems — Part 1: Determination of explosion indices of combustible dusts in air*, or ISO/IEC/UL 80079-20-2, *Explosive atmospheres — Part 20-2: Material characteristics — Combustible dusts test methods*, for procedures for determining the explosibility of dusts. A material that is found to not present an explosible mixture could still be an ignitable fiber/flying, as defined in 3.3.38. Historically, the explosibility condition has been described as presenting a flash fire or explosion hazard. It could be understood that the potential hazard due to the formation of an explosible mixture when suspended in air at standard atmospheric pressure and temperature would include ignition. [499, 2021]

While this standard includes larger yet still hazardous materials as a subset of combustible dust, NFPA 70 addresses them separately for purposes of defining the appropriate electrical classification. Although the hazard is the same when dispersed in a cloud, the electrical installation to prevent ingress of combustible fibers/flyings is different.

▲ A.3.3.12.1 Combustible Metal Dust. Dust from some processes can contain various amounts or concentrations of organic material. The burning characteristics from the mixture as determined from testing are used to distinguish between a combustible metal dust and a combustible dust.

A.3.3.12.3 Metal Dust. Dust from some processes may contain various amounts or concentrations of organic material. The burning characteristics from the mixture as determined from testing are used to distinguish between a combustible metal dust and a combustible dust.

■ A.3.3.13 Combustible Particulate Solid. Combustible particulate solids include dusts, fibers, fines, chips, chunks, flakes, or mixtures of these. The term *combustible particulate solid* addresses the attrition of material as it moves within the process equipment. Particle abrasion breaks the material down and produces a mixture of large and small particulates, some of which could be small enough to be classified as dusts. Consequently, the presence of dusts should be anticipated in the process stream, regardless of the starting particle size of the material. [652, 2019]

The terms *particulate solid*, *dust*, and *fines* are interrelated. It is important to recognize that while these terms refer to various size thresholds or ranges, most particulate solids are composed of a range of particle sizes making comparison to a size threshold difficult. For example, a bulk material that is classified as a particulate solid could contain a significant fraction of dust as part of the particle size distribution. [652, 2019]

While hazards of bulk material are addressed in this document using the provisions related to particulate solids, it might be necessary to apply the portions of the document relating to dust where there is potential for segregation of the material and accumulation of only the fraction of the material that fits the definition of dust. Furthermore, it is difficult to establish a fractional cutoff for the size threshold, such as 10 percent below the threshold size or median particle size below the threshold size, as the behavior of the material depends on many factors including the nature of the process, the dispersibility of the dust, and the shape of the particles. [652, 2019]

For the purposes of this document, the term *particulate solid* does not include an upper size limitation. This is intended to

encompass all materials handled as particulates, including golf balls, pellets, wood chunks and chips, and so forth. [652, 2019]

The term *particulate solid* is intended to include those materials that are typically processed using bulk material handling techniques such as silo storage, pneumatic or mechanical transfer, etc. While particulate solids can present a fire hazard, they are unlikely to present a dust deflagration hazard unless they contain a significant fraction of dust, which can segregate and accumulate within the process or facility. [652, 2019]

Dusts traditionally were defined as material 420 μm or smaller (i.e., capable of passing through a U.S. No. 40 standard sieve). For consistency with other standards, 500 μm (i.e., capable of passing through a U.S. No. 35 standard sieve) is now considered an appropriate size criterion. Particle surface area-to-volume ratio is a key factor in determining the rate of combustion. Combustible particulate solids with a minimum dimension more than 500 μm generally have a surface-to-volume ratio that is too small to pose a deflagration hazard. Flat platelet-shaped particles, flakes, or fibers with lengths that are large compared to their diameters usually do not pass through a 500 μm sieve, yet could still pose a deflagration hazard. Many particulates accumulate electrostatic charges in handling, causing them to attract each other, forming agglomerates. Often, agglomerates behave as if they were larger particles, yet when they are dispersed they present a significant hazard. Consequently, it can be inferred that any particulate that has a minimum dimension less than or equal to 500 μm could behave as a combustible dust if suspended in air or in the process-specific oxidizer. If the minimum dimension of the particulate is greater than 500 μm , it is unlikely that the material would be a combustible dust, as determined by test. [652, 2019]

Typically, the term *fines* refers to the fraction of material that is below 75 μm or that will pass through a 200-mesh sieve. Alternatively, fines can be characterized as the material collected from the final dust collector in a process or the material collected from the highest overhead surfaces in a facility. Fines typically represent a greater deflagration hazard than typical dusts of the same composition because they are more likely to remain suspended for an extended period of time and to have more severe explosion properties (higher K_{St} , lower MIE, etc.). [652, 2019]

For purposes of determining appropriate electrical installation requirements for combustible particulate solids, NFPA 499 has defined three material subgroups that can warrant establishing hazardous (classified) locations. Combustible dusts, per NFPA 499, are materials with a particle size less than 500 μm that can propagate a deflagration when suspended in a cloud, as determined by test. Combustible fibers/flyings are larger than 500 μm in at least one dimension, yet can still propagate a deflagration in a cloud. Both of these first two subgroups present flash-fire or explosion hazards when suspended in a cloud, as well as fire hazards when in a layer. Ignitable fibers/flyings are larger than 500 μm in at least one dimension, but either are too large or too agglomerated to suspend in the typical test or do not propagate a deflagration in a cloud. Ignitable fibers/flyings do not present a flash-fire or explosion hazard, yet still present a fire hazard when in a layer. All three of these subgroups defined in NFPA 499 are included in the term *combustible particulate solid* as defined and used in NFPA 652. Combustible fibers/flyings as defined in NFPA 499 are inclu-

ded in the term *combustible dust* as used and defined in NFPA 652. [652, 2019]

NFPA 70 provides different installation requirements for each of these three material subgroups. Materials smaller than 500 μm require more stringent dust exclusion designs (i.e., Class II or Zone Group IIIB) than materials larger than 500 μm (i.e., Class III or Zone Group IIIA). The exception to this is combustible metals, where both combustible metal dust and combustible metal fibers/flyings require Class II or Zone Group IIIC installations. Ignitable fibers/flyings additionally require lower maximum surface temperatures than combustible fibers/flyings for certain electrical equipment subject to overload conditions. When a hazardous (classified) location is established to address the presence of more than one of the three subgroups, the more stringent electrical installation requirements should be applied. [652, 2019]

A.3.3.15 Critical Process. The following are examples of critical processes, but the list is not all-inclusive:

- (1) Any operation such as mixing or screening of tantalum powder that results in a dust cloud
- (2) A process that raises tantalum to an elevated temperature, where a failure could cause the tantalum to be exposed to a source of oxygen (including atmospheric air)
- (3) A furnace or passivation process that could result in a fire or explosion if a catastrophic failure allowed the tantalum to be exposed to a source of oxygen
- (4) A furnace or other equipment that contains tantalum at temperatures sufficient to cause auto-ignition if not cooled over a period of time

A.3.3.21.1 Dust Collection System. A typical dust collection system consists of the following:

- (1) Hoods — devices designed to contain, capture, and control airborne dusts by using an induced airflow in close proximity to the point of dust generation (local exhaust zone) to entrain fugitive airborne dusts.
- (2) Ducting — includes, but is not limited to, piping, tubing, and fabricated duct, used to provide the controlled pathway from the hoods to the dust collector (AMS). Maintaining adequate duct velocity [usually above 1219 m/min (4000 ft/min)] is a key factor in the proper functioning of the system.
- (3) Dust collector — an AMS designed to separate the conveyed dusts from the conveying air stream. Usually these devices have automatic methods for cleaning the filter media to allow extended use without blinding. In some systems, a scrubber or similar device is used in place of the filter unit.
- (4) Fan package — an AMD designed to induce the air or gas flow through the entire system.

The system is designed to collect only suspended dusts at the point of generation and not dusts at rest on surfaces. The system is also not designed to convey large amounts of dusts as the system design does not include friction loss due to solids loading in the pressure drop calculation (such a system would be either a pneumatic conveying/transfer system or centralized vacuum cleaning system). Thus, material loading must be minimal compared to the volume or mass of airflow.

A.3.3.21.4 Dust Hazards Analysis (DHA). In the context of this definition it is not intended that the dust hazards analysis (DHA) must comply with the process hazards analysis (PHA) requirements contained in OSHA regulation 29 CFR 1910.119,

“Process Safety Management of Highly Hazardous Chemicals.” While the DHA can comply with OSHA PHA requirements, other methods can also be used (see *Annex B of NFPA 652*). However, some processes might fall within the scope of OSHA regulation 29 CFR 1910.119, and there could be a legal requirement to comply with that regulation. [652, 2019]

A.3.3.23 Explosible. For dusts, explosibility is determined as described in Section 5.4. See also 5.4.3 in NFPA 652. For hybrid mixtures, see NFPA 68.

A.3.3.27 Fire-Resistive. The requirements are described in NFPA 220.

A.3.3.29 Flash Fire. A flash fire requires an ignition source and an atmosphere containing a flammable gas, a flammable vapor, or finely divided combustible particles (e.g., metal dust) having a concentration sufficient to allow flame propagation. Flammable gas, flammable vapor, and organic dust flash fires typically generate temperatures from 1000°F to 1900°F (538°C to 1038°C). Metal dust flash fires can generate higher temperatures [see *Table A.1.1.3(a)*]. The extent and intensity of a flash fire depend on the size and concentration of the gas, vapor, or dust cloud. When ignited, the flame front expands outward in the form of a fireball. High thermal radiation heat flux produced by most metals significantly enlarges the hazard areas beyond the fire ball.

Another type of short duration fire can occur when a stream of combustible metal or vapor flows past a stationary ignition source (sometimes referred to as a jet fire). This short duration flame poses similar hazards to a flash fire in the form of a deflagration and should be considered as part of the dust hazard analysis (DHA).

A.3.3.37 Hybrid Mixture. The presence of flammable gases and vapors, even at concentrations less than the lower flammable limit (LFL) of the flammable gases and vapors, adds to the violence of a dust-air combustion. [654, 2017]

The resulting dust-vapor mixture is called a *hybrid mixture* and is discussed in NFPA 68. In certain circumstances, hybrid mixtures can be deflagrable, even if the dust is below the MEC and the vapor is below the LFL. Furthermore, dusts determined to be nonignitable by weak ignition sources can sometimes be ignited when part of a hybrid mixture. [654, 2017]

Examples of hybrid mixtures are a mixture of methane, coal dust, and air or a mixture of gasoline vapor and gasoline droplets in air. [654, 2017]

A.3.3.38 Ignitable Fibers/Flyings. Section 500.5 of NFPA 70 defines a Class III location as one where ignitable fibers/flyings are present, but not likely to be in suspension in the air in quantities sufficient to produce ignitable mixtures. This description addresses fibers/flyings that do not present a flash-fire hazard or explosion hazard by test. This could be because those fibers/flyings are too large or too agglomerated to be suspended in air in sufficient concentration, or at all, under typical test conditions. Alternatively, this could be because they burn so slowly that, when suspended in air, they do not propagate combustion at any concentration. [499, 2021]

In this document the zone classification system includes ignitable fibers/flyings as a fire hazard in a layer, which is not addressed in the IEC zone system (see IEC 60079-10-2, *Explosive atmospheres — Part 10-2: Classification of areas — Explosive dust atmospheres*). Where these are present, the user could also

consider installation in accordance with Article 503 of NFPA 70. [499, 2021]

A.3.3.39 Incipient-Stage Fire. Properly trained personnel who work with specific combustible metals know their hazards. Such personnel are best equipped to extinguish metal fires in their incipient stage. Training should include sufficient information to determine if extinguishment can be accomplished safely and effectively.

A.3.3.40 Industry- or Commodity-Specific NFPA Standard. It is possible that within a single building or enclosure more than one industry- or commodity-specific NFPA standard could apply. The following documents are commonly recognized as commodity-specific standards:

- (1) NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities*
- (2) NFPA 120, *Standard for Fire Prevention and Control in Coal Mines*
- (3) NFPA 484, *Standard for Combustible Metals*
- (4) NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*
- (5) NFPA 655, *Standard for Prevention of Sulfur Fires and Explosions*
- (6) NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*

[652, 2019]

A.3.3.42.2 Pyrophoric Material. Dispersions of alkali metals in organic solvents present special concerns. In addition to the water reactivity/pyrophoricity due to the reactive metal, the solvent presents the concerns of flammable or combustible liquids and vapors. In addition to the SDS provided by the supplier of the material, NFPA 30 and NFPA 77 are applicable to addressing the problems of combustible liquids and vapors.

A.3.3.42.3 Spark-Resistant Material. See AMCA Standard 99-0401, "Classifications for Spark Resistant Construction," for additional information.

A.3.3.44 Mesh Size. Table A.3.3.44 provides mesh sizes.

A.3.3.45 Metal. An opaque lustrous elemental chemical substance that is a good conductor of heat and electricity and, when polished, a good reflector of light. Commercially pure metals have no alloying elements deliberately added. Most elemental metals are malleable and ductile and are, in general, denser than other elemental substances. As to structure, metals can be distinguished from nonmetals by their atomic binding and electron availability.

A.3.3.45.2 Combustible Metal. See A.1.1.3 for further information on determining the characteristics of metals.

A.3.3.45.3 Legacy Metals. These specific metals had individual chapters in previous editions of NFPA 484. For consistency and convenience, these requirements have been pulled into a single chapter. The requirements have not changed. See 1.1.3 for additional guidance for alloys.

A.3.3.45.5 Metal-Containing Mixture. Intentional mixtures range from formulations by blending or compounding of metals with non-metals (organics, salts, inorganics) for use as intermediates, final products, inertants, or for recycling or waste treatment. Examples of mixtures as products include powder coating formulations and blended metals for powder metallurgy or alloy production. Rock dusts (such as limestone,

Table A.3.3.44 Mesh Designations

U.S. Standard Mesh Designation	Mesh Size		
	mm	µm	in.
4	4.750	4750	0.1870
5	4.000	4000	0.1570
6	3.350	3350	0.1320
7	2.800	2800	0.1110
8	2.360	2360	0.0937
10	2.000	2000	0.0787
12	1.700	1700	0.0661
14	1.400	1400	0.0555
16	1.180	1180	0.0469
18	1.000	1000	0.0394
20	0.850	850	0.0331
25	0.710	710	0.0278
30	0.600	600	0.0234
35	0.500	500	0.0197
40	0.425	425	0.0165
45	0.355	355	0.0139
50	0.300	300	0.0117
60	0.250	250	0.0098
70	0.212	212	0.0083
80	0.180	180	0.0070
100	0.150	150	0.0059
120	0.125	125	0.0049
140	0.106	106	0.0041
170	0.090	90	0.0035
200	0.075	75	0.0029
230	0.063	63	0.0025
270	0.053	53	0.0021
325	0.045	45	0.0017

dolomite, and magnesite) have been used as solid inertants to inert or suppress dust explosions. Examples of mixtures for recycling or waste treatment are metal turnings, chips, fines, powder, or dust from the finishing operation of two or more metals or alloys; and metal turnings, chips, fines, powder or dust containing debris from abrasive media (alumina, silicon carbide, boron carbide, diamond, cubic boron nitride, garnet and quartz) from grinding, honing, lapping, superfinishing, polishing, pressure blasting or barrel finishing; water, cleaning agents and/or cutting oils. Metal alloys, organometallics, salts and metal oxides, sulfides, silicates, etc. are not metal mixtures because they are bonded either chemically on in their lattice structures. Mixtures do not include contamination. The original composition could be segregated into the individual components during size reduction or handling.

A.3.3.46 Minimum Explosible Concentration (MEC). Minimum explosible concentration is defined by the test procedure in ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*.

The MEC is sometimes incorrectly referred to as the lower flammable limit (LFL) or lower explosive limit (LEL). Dusts have no upper explosive concentration.

A.3.3.47 Minimum Ignition Energy. The standard test procedure for MIE of combustible particulate solids is ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, and the standard test procedure for MIE of flammable vapors is ASTM E582, *Standard Test Method for Minimum Ignition Energy and Quenching Distance in Gaseous Mixtures*. [654, 2017]

N A.3.3.49 Nanometal Powder. Although nanomaterials are usually defined as particles smaller than 100 nanometers (0.1 μm), larger particulates with diameters of almost 500 nanometers (0.5 μm) also exhibit special ignitability characteristics and enhanced combustibility and explosibility. For example, LOC data reported by Mittal 2014 shows the LOC for magnesium is 5 percent for a particle size range of 38 μm to 125 μm , and decreases to 3 percent for a particle size of 400 nanometers (0.4 μm).

A.3.3.50 Noncombustible. Materials reported as noncombustible, where tested in accordance with ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, are considered noncombustible materials.

N A.3.3.53 Pneumatic Conveying System. Pneumatic conveying systems include a wide range of equipment systems utilizing air or other gases to transport solid particles from one point to another. A typical system comprises the following:

- (1) A device used to meter the material into the conveying air stream
- (2) Piping, tubing, hose, etc., used to provide the closed pathway from the metering device to the AMS
- (3) An AMS designed for the separation of comparatively large amounts of material from the conveying air/gas stream
- (4) An additional metering device (typically a rotary airlock valve or similar device) that might be used to allow discharge of the separated material from the conveying air stream without affecting the differential pressure of the system
- (5) An AMD designed to produce the necessary pressure differential and air/gas flow in the system (positive or negative)

[652, 2019]

A pneumatic conveying system requires the amount of material conveyed by the system to be considered as a major factor in the system pressure drop calculations. [652, 2019]

Both positive and negative (i.e., vacuum) differential pressure are used for pneumatic conveying. The decision of which is the best for a specific application should be based upon a risk analysis, equipment layout, and other system operational and cost factors. [652, 2019]

Dense phase conveying can also be considered for the application, especially with more hazardous materials (e.g., low MIE). The inherent design and operational features of this approach can provide significant safety and operational advantages over other types of pneumatic conveying systems. [652, 2019]

For high-risk materials (e.g., some metal powders with low MIE), the use of a “closed-loop” pneumatic conveying system (i.e., dilute, dense, or semi-dense phase) with a suitable inert gas as the conveying medium is a feasible approach for transferring such materials from one location to another. Special design considerations are necessary, including the use of qualified design engineers and equipment system vendors.

A.3.3.56.1 Aluminum Flake Powder. Certain “nondusting” grades of aluminum flake powder are being produced. Although they exhibit less tendency to be dispersed into a dust cloud, the precautions described in this standard should nevertheless be observed.

A.3.3.56.3 Aluminum Powder. The length, width, and thickness of an atomized particle or granule are all of approximately the same order, the length dimension probably not exceeding two or three times the thickness dimension. The length or width of a flake is several hundred times its thickness. Granules are generally powders larger than 75 μm (microns) (200 mesh).

Δ A.3.3.56.4 Combustible Metal Powder. See NFPA 499 or NFPA 497 for information on explosibility parameters of combustible dusts.

A.3.3.57 Powder Production Plant. Facilities or buildings in which powder or combustible dust is produced incidentally to operations are not considered powder production plants.

A.3.3.60 Recycling. Recycling includes, but is not limited to, mechanical and chemical processing, crushing, grinding, shearing, baling, compacting, and so forth. Where a new chemical compound is made, or materials are consolidated or processed such that its form is no longer recognizable from the original raw material, it is considered manufacturing not recycling.

A.3.3.62.1 Magnesium Ribbon. It should be considered a powder for storage.

N A.3.3.63 Risk Assessment. A risk assessment is a process that performs the following:

- (1) Identifies hazards
- (2) Quantifies the consequences and probabilities of the identified hazards
- (3) Identifies hazard control options
- (4) Quantifies the effects of the options on the risks of the hazards
- (5) Establishes risk tolerance criteria (i.e., maximum tolerable levels of risk)
- (6) Selects the appropriate control options that meet or exceed the risk acceptability thresholds

Steps 1 through 3 are typically performed as part of a dust hazards analysis (DHA). Risk assessments can be qualitative, semiquantitative, or quantitative. Qualitative methods are usually used to identify the most hazardous events. Semiquantitative methods are used to determine relative hazards associated with unwanted events and are typified by indexing methods or numerical grading. Quantitative methods are the most extensive and use a probabilistic approach to quantify the risk based on both frequency and consequences. (See *SFPE Engineering Guide to Fire Risk Assessment* or *AICHE Guidelines for Hazard Evaluation Procedures* for more information.)

A.3.3.69 Sponge. Sponge can contain dust and fines that can become airborne when the material is handled. If present in sufficient quantity, the dust and fines can cause increased fire risk.

A.3.3.74 Thermite Reaction. There is a potential for a thermite reaction between metal alloys and iron oxide at elevated temperatures.

Iron scale and molten metal can create a thermite reaction. The interior of a crucible furnace, normally known as the “setting,” is a critical area of concern. With the use of sulfur hexafluoride (SF_6) and other protective atmospheres, the problem of iron scale forming above the melt and reacting if it falls into the melt is a concern.

N A.4.3.2 Given the fast-acting nature of flash fire, deflagration, and explosions, the stated life safety objective recognizes the difficulty, if not the impossibility, of protecting occupants in the immediate proximity of the ignition. Thus, the stated objective is to protect occupants not in the immediate proximity of ignition. However, all available practices should be employed to ensure the safety of all persons both near and far from the ignition. An example of this might be the standard's prescriptive exception relative to the less than 8 ft³ (0.2 m³) air-material separator not requiring protection; however, the intent of the objective is to consider the effect of deflagration to occupants in the immediate area of the small air-material separator and mitigate this hazard if possible. Likewise, the standard has not defined "immediate proximity" in that this could mean within just feet of the hazard or within the same building or structure and leaves that judgment to the user. The intent of the objective is to employ all available and reasonable protection, techniques, and practices to protect all occupants understanding that it might not always be achievable. [652:A.4.2.1.1]

N A.4.3.4 Other stakeholders could also have mission continuity goals that will necessitate more stringent objectives as well as more specific and demanding performance criteria. The protection of property beyond maintaining structural integrity long enough to escape is actually a mission continuity objective. [652:A.4.2.2]

The mission continuity objective encompasses the survival of both real property, such as the building, and the production equipment and inventory beyond the extinguishment of the fire. Traditionally, property protection objectives have addressed the impact of the fire on structural elements of a building as well as the equipment and contents inside a building. Mission continuity is concerned with the ability of a structure to perform its intended functions and with how that affects the structure's tenants. It often addresses post-fire smoke contamination, cleanup, and replacement of damaged equipment or raw materials. [652:A.4.2.2]

N A.4.3.5 Adjacent compartments share a common enclosure surface (e.g., wall, ceiling, floor) with the compartment of fire or explosion origin. The intent is to prevent the collapse of the structure during the fire or explosion. [652:A.4.2.3]

N A.4.3.5(1) This concerns the potential release of hazardous materials from the production of combustible metals. Examples include, but are not limited to, hydrogen, argon, helium, titanium tetrachloride, silicon tetrachloride, and chlorine.

N A.4.3.5(2) See A.6.2.4.1.

N A.4.3.8 Usually, a facility or process system is designed using the prescriptive criteria until a prescribed solution is found to be infeasible or impracticable. Then the designer can use the performance-based option to develop a design, addressing the full range of fire and explosion scenarios and the impact on other prescribed design features. Consequently, facilities are usually designed not by using performance-based design methods for all facets of the facility but rather by using a mixture of both design approaches as needed.

A.4.4 It is essential to have thorough written documentation, as the slightest changes to procedures, processes, and/or equipment, including from suppliers, can have a dramatic impact on the overall hazard analysis. Changes include something as seemingly benign as process materials, replacements-in-kind from a different manufacturer, the same manufacturer

using new methods to produce the product, or changes in formulation. These changes from a supplier's end can impact the characteristics of the processes and/or materials.

A.4.5.1 One method by which this requirement can be satisfied is with a hazard analysis conducted in accordance with the methods outlined by the American Institute of Chemical Engineers' Center for Chemical Process Safety in *Guidelines for Hazard Evaluation Procedures*.

To determine if a dust deflagration hazard exists, consider the following:

- (1) Is the dust explosible? Determine using ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, or its equivalent.
- (2) Determine where in the process a dust cloud sufficient to support a deflagration could occur. Use loss records and knowledge of process conditions to make this assessment.
- (3) Identify likely ignition sources. Recognize that ignition sources are complex and not always predictable. It is best to assume ignition is possible in all cases.
- (4) Assess the likelihood of an event. For example, a material with a low MIE has a greater likelihood of ignition, all else being equal. Determine MIE, if appropriate, using ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*.
- (5) In terms of a worst-case scenario, consider the predictable consequences. Start with predictable primary events and then secondary events.
- (6) If the consequences are intolerable to either the owner/operator or the AHJ, ask the following:
 - (a) Can the risk be eliminated?
 - (b) Can controls be applied to minimize the likelihood?
 - (c) Can the risk be tolerated utilizing mitigation techniques to reduce or control the consequences?

A.4.6 Flash fire-resistant garments are significantly more effective than ordinary clothing in preventing burn injury on exposure to low to moderate heat fluxes, but they cannot prevent burn injuries to personnel immersed in combustible metal flash fires. (See the U.S. Chemical Safety Board's case study report on the Hoeganaes Corporation's fatal flash fires.)

A.4.6.1.2 Primary PPE for molten metals would normally be expected to be worn by personnel working near operational foundry furnaces and metal casting areas. Primary PPE for dust flash fires would normally be expected to be worn by personnel working with or near equipment and storage vessels/silos containing powdered metals, and by personnel responsible for maintenance or repairs of combustible metal dust handling or storage equipment (such as dust collectors) and open top containers. This would also include personnel responsible for cleaning combustible metal dusts.

A.4.6.2.3 Performance requirements described in ASTM F1002 for primary protective clothing include the following considerations:

- (1) Fabric flammability, before and after 25 cycles of washing or dry cleaning
- (2) Fabric strength
- (3) Fabric adhesion
- (4) Molten metal shedding when tested using ASTM F955, *Standard Test Method for Evaluating Heat Transfer through Materials for Protective Clothing Upon Contact with Molten Substances*

(5) Heat transfer through fabric

There are also requirements to cover potentially exposed areas as completely as possible, to not contain external pockets (that could collect and retain molten materials), to not interfere with work function, and to be easily removable. There are also requirements to cover potentially exposed areas as completely as possible, to not contain external pockets (that could collect and retain molten materials), to not interfere with work function, and to be easily removable.

▲ **A.4.6.3.1** NFPA 2113 describes requirements and criteria for wearing garments made and tested in accord with NFPA 2112.

▲ **A.4.6.3.2** Testing has shown that the 84 kW/m² heat flux used in the NFPA 2112 garment-equipped mannequin flash fire test is only 25 percent to 32 percent of an iron dust flash fire heat flux. Other combustible metals have higher flame temperatures that can produce even higher heat fluxes. Therefore, the NFPA 2112-compliant garments are not expected to protect personnel against large, extended duration, flash fires involving combustible metal dusts. More stringent flame-resistant garment requirements, such as those for fire-fighting applications, NFPA 1971 and for arc flash protection; *ASTM F2621, Standard Practice for Determining Response Characteristics and Design Integrity of Arc Rated Finished Products in an Electric Arc Exposure*, might provide better protection for metal dust flash fires, but there are no test data to substantiate their performance for metal dust fires.

A.4.6.3.6 Heat-resistant fabrics include, but are not limited to, Kevlar, Nomex, and heavy leather.

A.4.6.3.7 Wool, silk, or synthetic fabrics that can accumulate high static electric charges should not be used in areas containing metal dusts with such low MIE values. Where static-dissipative safety shoes are used, a testing program to confirm that the shoes are static-dissipating should be in place.

A.4.6.4.4 Wool, silk, or synthetic fabrics that can accumulate high static electric charges should not be used in areas containing metal dusts with such low MIE values.

A.4.6.4.5.1 Burning combustible metals will burn through material used in the construction of most fire fighter protective clothing. Some features (e.g., heavy quilted linings, aluminized outer shells) can reduce this risk. The self-contained breathing apparatus (SCBA) facepiece eye protection worn by fire fighters adequately protects against the effects of a lithium fire, with the exception of the intense light given off by burning lithium. (See *NFPA 1500*.)

Specific testing indicates that white-light levels emitted from burning lithium exceed recommended levels, and extended lithium fire experience has shown that this intense light can cause serious damage to unprotected eyes. A clip-on adapter over an SCBA facepiece with a shaded glass lens equivalent to a No. 6 welding lens has been used successfully to reduce such hazards. A darker lens tends to obstruct the fire fighter's view to an unacceptable degree.

A.4.8.3.1 A relatively small initial dust deflagration can disturb and suspend in air dust that has been allowed to accumulate on the flat surfaces of a building or equipment. Such a dust cloud provides fuel for the secondary deflagration, which can cause damage. Reducing significant additional dust accumulations is therefore a major factor in reducing the hazard in areas where a dust hazard can exist.

A.4.8.3.4 A building could be considered as a single dust flash-fire hazard area, or as a collection of smaller, separated dust flash-fire hazard areas. When the owner/operator chooses to consider the building as a single area, then the hazard analysis should consider the entire building floor area and the considerations for mitigation apply to the entire building. Where the dust flash-fire hazard areas are sufficiently distant to assert separation and the owner/operator chooses to consider each hazard area separately, then the hazard analysis should consider each separated area and the considerations for mitigation applied to each area independently. Due consideration should be given to overhead dust accumulations, such as on beams or ductwork, which would negate the use of separation to limit dust flash-fire hazard areas. If the separation option is chosen, a building floor plan, showing the boundaries considered, should be maintained to support housekeeping plans.

■ **A.4.9** Many organometallic compounds — also referred to as metal organics — are pyrophoric, react violently with water, and burn with characteristics similar to combustible metals. Guidelines for safe handling of these materials are available from organometallic compound manufacturers such as www.fmclithium.com/portals/fmclithium/.../fmc_spclty-cat_web.pdf and <https://www.akzonobel.com/polymer/safety/organometallics/>. Manufacturer safety data sheets for particular organometallic compounds have more specific characterizations of the flammability and reactivity characteristics as well as guidelines on handling, storage, firefighting, and disposal.

A.5.1 Combustible metals and dusts and alloys of those metals provide varying degrees of hazard for fire and explosion risk. Hazard assessment for process and facilities is difficult without quantitative test data for the specific materials and their forms. The foundation for the primary basis of safety, as well as the extent to which other NFPA standards require compliance, is a function of the actual properties of the materials under consideration. Reliance on historical, dated, or similar available test data is highly discouraged. Specific properties of the specific forms of combustible metals and dusts will dictate test results and the corresponding level of risk. No generalizations or substitutions of a similar kind are acceptable or prudent to use.

The requirements contained in this document provide the minimum requirements necessary to facilitate safe manufacturing, handling, and processing of these materials. Combustible metals can be made in specific forms that require additional safeguards to provide safe handling. The specific nature of additional safeguards should be determined by using the results of a hazard assessment.

A.5.1.5 Some materials are subject to change, such as oxidation or other chemical reaction, that could affect the test results. Precautions, such as inerting or vacuum packing, should be taken to preserve the test sample integrity. Examples of variations in process and material conditions include changes in the abrasive materials in sanding and polishing operations, cutting blade wear and cutting oil contamination causing changes in cuttings and dust particle size distribution and composition, and ambient temperature and humidity variations affecting the extent of metal oxidation. Metal recycling facilities experience large variations in particulate and contaminant compositions of received materials. These variations should be assessed to determine when and where to obtain sample materials that represent the most combustible compositions and the smallest particle sizes. If combustibility

and particle size variations cannot be assessed without testing, multiple samples should be collected and submitted for testing.

A.5.2 The physical hazards of metals and metal-containing metals in combustible form depend on material properties. Changes in the form or composition of the material can result in a change in the type and degree of hazard. The results of combustibility and explosibility screening tests are meaningful when the sample subject to testing is well characterized and reported with the results. The age of a sample can influence test results; therefore, fresh samples are likely more representative and preferred for determination of combustibility.

A.5.2.1 Examples of identifiers include the process equipment collected from, the lot number, etc. A photographic record of the sample location can be used to further document and identify samples, and the photo should include a date stamp. If the sample is collected from a drum, the drum label can be photographed. If the sample is collected from on top of or inside process equipment, an overview photograph and photographs before and after sampling can be used to identify different process equipment and heights. Samples should be collected from rooms and sources known to pose or amplify combustible dust fires and explosions.

Special consideration should be given to metal containing samples from equipment such as dust collectors, impact equipment, bins, processing equipment, ovens, furnaces, dryers, conveyors, bucket elevators, etc. If it is taken from a dust collection or pneumatic conveying system, the sample should represent the hazard subject to evaluation.

Samples should be collected from rooms and buildings where metals might exist in combustible form, including rooms where abrasive blasting, cutting, grinding, polishing, mixing, conveying, sifting, screening, bulk handling or storage, packaging, agglomeration, and coating are performed.

A.5.2.2 See Figure A.5.2.2 for typical basic material characterization.

A.5.3.1 This preliminary screening test used to demonstrate fire risk is the basis for the regulations governing the transport of dangerous goods for United Nations (UN) regulations, DOT, International Air Transport Association (IATA), and the International Maritime Dangerous Goods (IMDG) Code.

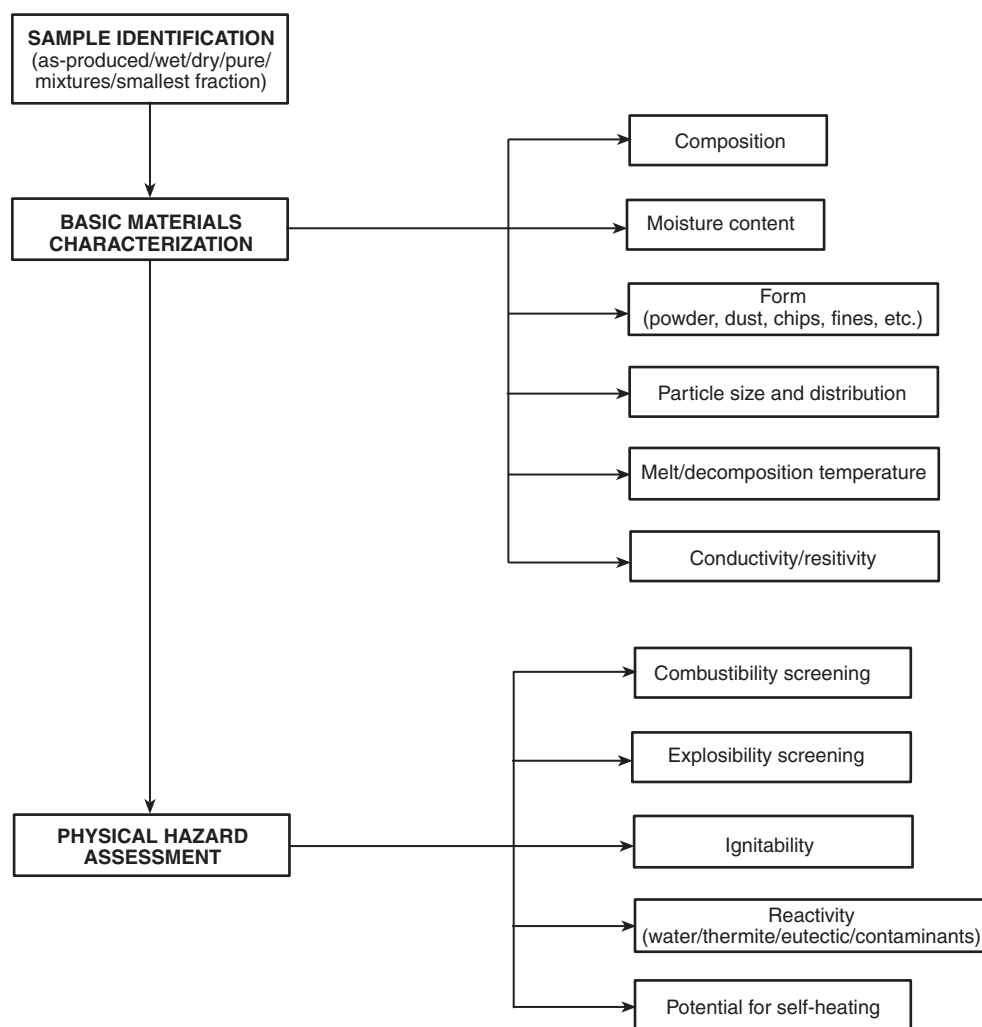


FIGURE A.5.2.2 Examples of Basic Materials Characterization.

The preliminary screening test is conducted in the following fashion:

- (1) The substance in its commercial form is formed into an unbroken strip or powder train about 250 mm (9.84 in.) long by 20 mm (0.79 in.) wide by 10 mm (0.39 in.) high on a cool, impervious, low-heat-conducting base plate.
- (2) A hot flame [minimum temperature of 1000°C (1832°F) from a gas burner] [minimum diameter of 5 mm (0.20 in.)] is applied to one end of the powder train until the powder ignites or for a maximum of 5 minutes. It should be noted whether combustion propagates along 200 mm (7.87 in.) of the train within a 20-minute test period.
- (3) If the substance does not ignite and propagate combustion either by burning with flame or smoldering along 200 mm (7.87 in.) of the powder train within the 20-minute test period, the material should not be considered a combustible metal, metal powder, or dust.
- (4) If the substance propagates burning of the 200 mm (7.87 in.) length of the powder train in less than 20 minutes, the full burning rate test should be conducted.

Because the specific form of the combustible metal, metal powder, or dust and the properties of the form determine the flammability and degree of combustibility of the material, it is critical that the substance be tested precisely in the condition in which it is processed or handled. Changes in particle size distribution, moisture content, degree of fines, and chemical composition can radically change the results. No generic substitute is allowable for accurate determination of fire risk.

Δ A.5.3.4 Results of the preliminary screening test can have one of the following results:

- (1) No reaction
- (2) Glowing, but no propagation along the powder train
- (3) Propagation, but too slow to include the test material in Division 4.1
- (4) Propagation sufficiently fast to qualify for inclusion in Division 4.1

If the results of the screening test show no reaction or glowing in the specific form, then that material can be considered noncombustible and does not fall under the requirements of this document.

If the results of the screening test show glowing but no propagation along the powder train, the material in the specific form should be considered a limited-combustible material. A larger scale propagation test could be considered to validate a negative result. Experience with these tests have shown that many metals will just produce glowing with a standard powder train test, yet will produce positive explosibility results in the tests described in Section 5.4 and in non-standardized flash fire tests. Therefore, the powder train tests for materials that glow can result in a misleading representation of the fire and flash fire hazards. Hazard analysis should be conducted to determine the extent to which the requirements of this document are applicable. It is recommended for general safety that the full requirements be met.

If the results of the screening test show propagation of the powder train, the material in the specific form should be considered a limited-combustible material and full compliance with the requirements of this document should be met.

If the results of the screening test show propagation of the powder train sufficiently fast that the form is classified as a Division 4.1 material, hazard analysis should focus on additional protocols and compliance with other NFPA standards.

Some nanometal powders, as well as some larger particulate pyrophoric metals, will ignite either on exposure to air or while handling during test preparations. These materials should be considered combustible and are covered by NFPA 484. One example of a metal that is not combustible in micrometer particle size but can be pyrophoric as a nanometal is copper (*see Krietsch 2015*).

A.5.3.5 If propagation of the powder train occurs along a length of 200 mm (7.87 in.) in 20 minutes or less, the burning rate test is required. The burning rate test requires specific preparation of the powder sample. The sample is prepared in a specific fixture as shown in Figure A.5.3.5.

Preparation of the sample for the burning rate test should be done according to the following description.

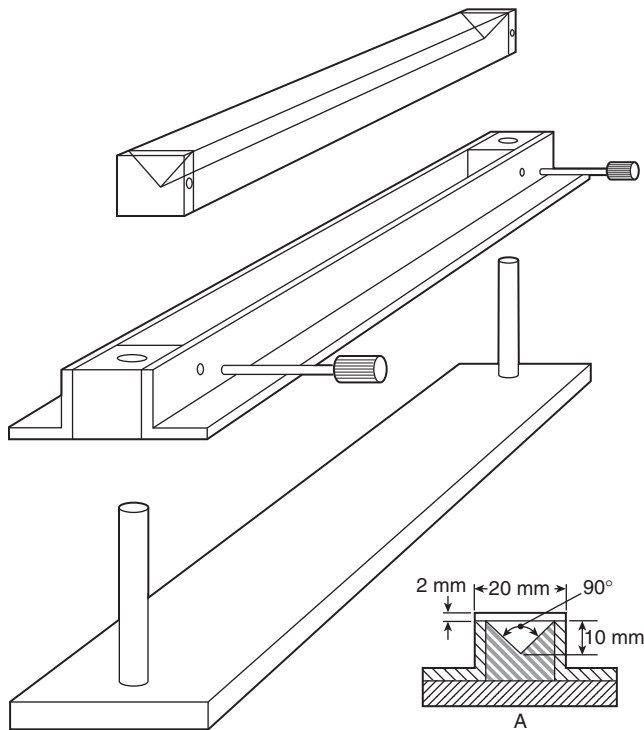
The powdered or granular substance, in its commercial form, must be loosely filled into a mold. The mold, which must be 250 mm (9.84 in.) long with a triangular cross section of inner height 10 mm (0.39 in.) and width 20 mm (0.79 in.), is used to form the train for the burning rate test. On both sides of the mold, in the longitudinal direction, two metal sheets are mounted as lateral limitations that extend 2 mm beyond the upper edge of the triangular cross section. An impervious, noncombustible, low-heat-conducting plate is used to support the sample train. The mold is then dropped three times from a height of 20 mm (0.79 in.) onto a solid surface. The lateral limitations are then removed, and the impervious noncombustible low-heat-conducting plate is placed on top of the mold, the apparatus inverted, and the mold removed. Pasty substances must be spread on a noncombustible surface in the form of a rope 250 mm (9.84 in.) in length with a cross section of about 100 mm² (0.16 in.²). In the case of a moisture-sensitive substance, the test must be carried out as quickly as possible after its removal from the container.

Test conditions are as follows:

- (1) The pile is arranged across the draft in a fume cupboard. The airspeed is sufficient to prevent fumes from escaping into the laboratory and is not varied during the test. A draft screen can be erected around the apparatus.
- (2) Any suitable ignition source such as a small flame or hot wire of minimum temperature 1000°C (1832°F) is used to ignite the pile at one end. When the pile has burned a distance of 80 mm (3.15 in.), the rate of burning is measured over the 100 mm (3.94 in.). The test is performed six times using a clean cool plate each time, unless a positive result is observed earlier.

The metal powder or metal alloy is classified in Division 4.1, and as such is considered readily combustible if it can be ignited and the reaction spreads over the whole length of the sample in 10 minutes or less.

A.5.3.5.1 The screening test is performed under atmospheric conditions; however, the process might be performed under other conditions, such as elevated temperature, excess oxygen, other gases, hybrid mixture, and elevated pressure, that could influence combustibility.



Note: For U.S. standard measurements, 1 mm = 0.039 in.

FIGURE A.5.3.5 Fixture for Preparation of Sample for Burning Rate Test.

A.5.4.1 Table A.5.4.1 gives a small sample of published ignition and explosion data on various sizes of aluminum powders.

N A.5.4.1.1 Many nanometal samples ignite upon compressed air injection into the ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, test vessel so that it becomes difficult to measure the pressure ratio used as the basis for a positive explosibility determination. (See Bouillard 2010 and Boilard 2013.)

Δ A.5.4.2 The determination of whether a sample of material is a combustible, explosible dust should be based on the explosibility screening test methodology provided in ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*. Alternatively, a standardized test method such as ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, can be used to determine dust explosibility.

There is some possibility that a sample will result in a false positive in the 20 L (5.25 gal) sphere when tested by the ASTM E1226 screening test or the ASTM E1515 test. This is due to the high energy ignition source over-driving the test. When the lowest ignition energy allowed by either method still results in a positive result, the owner/operator can elect to determine whether the sample is a combustible dust with screening tests performed in a larger scale ($\geq 1 \text{ m}^3$) enclosure, which is less susceptible to over-driving.

For some combustible metals, it has been found that the K_{st} and P_{max} values will be higher in a larger scale enclosure. This means that conversely there is some possibility that a sample will result in a false negative in the 20 L (5.25 gal) sphere when tested by the ASTM E1226 screening test or the ASTM E1515

test. If a screening test produces evidence of combustion yet a test pressure below the threshold, it is recommended to validate this negative result in the larger scale 1 m^3 enclosure. This possibility is considered more likely for metals with calculated maximum adiabatic flame temperature equivalent to magnesium and higher. NFPA 68 mentions specifically aluminum, hafnium, magnesium, tantalum, and titanium as metals that could exhibit the same phenomena. [See also Table A.1.1.3(a).]

A.5.4.3 Explosive properties are dramatically affected by changes in physical properties, chemical composition, particle size distribution, amount of fines, and mean particle size. These changes can be due to variations in process operating parameters, substitutions in shop and feedstock supplies, changes to shop supply providers, and process or transport equipment changes including normal equipment wear. Test sample selection should include an assessment of the extent of these nominal process, equipment and material variations in order to select a sample representative of the finest particulates and compositions that are likely to enhance explosibility. If explosibility and particle size variations cannot be assessed without testing, multiple samples should be collected and submitted for testing.

If normal composition of the material includes a high moisture content but subsequent drying or exposure to elevated temperature of the material occurs, it is highly advisable that parallel testing of the material at low moisture content be performed. Some materials are subject to change, such as oxidation or other chemical reaction that could affect the test results. Precautions, such as inerting or vacuum packing, should be taken to preserve the test sample integrity during packaging, shipping and testing.

Δ A.5.4.4 Testing for the minimum ignition energy (MIE) of a combustible particulate is carried out in accordance with recognized international standards ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, and BS 5958-1, *Code of Practice for Control of Undesirable Static Electricity: General Considerations*.

The MIE test uses a Hartmann tube vertically mounted with a 63 mm inside diameter and 1 L volume. The Hartmann tube is outfitted with a compressed-air dust dispersion system and brass electrodes. Different types of igniters are used for this test to produce sparks. One type, which uses high-voltage capacitance sparks, can produce sparks of widely varying energy. In the test, a measured weight of the test sample is dispersed through a spark of known energy. The spark energy and the weight of the sample are varied to produce different combinations of dust concentration and spark energy. Normally the dust concentration is high. The spark energy is reduced until no dust ignition occurs. The value of spark energy at which ignition ceases is the MIE.

Explosibility Test. The explosibility test serves to identify the maximum unvented deflagration pressure a material is capable of producing under optimum conditions of dust cloud concentration, as well as the maximum speed of the explosion.

This explosion severity test is carried out in accordance with the ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, or EN 14034-1, *Determination of Explosion Characteristics of Dust Clouds – Part 1: Determination of the Maximum Explosion Pressure P_{max} of Dust Clouds*; and EN 14034-2, *Determination of Explosion Characteristics of Dust Clouds – Part 2: Determination of the Maximum Rate of Explosion Pressure Rise $(dP/dt)_{max}$ of Dust Clouds*.

Table A.5.4.1 Atomized Aluminum Particle Ignition and Explosion Data

Particle Size (d_{50}) (μm)	BET (m^2/g)	MEC (g/m^3)	P_{max} (psi)	dP/dt_{max} (psi/sec)	K_{st} (bar·m/ sec)	Sample Concentration That Corresponds to P_{max} and dP/dt_{max}	MIE (mJ)	LOC (%)	Most Easily Ignitable Concentration (g/m^3)
<i>Nonspherical, Nodular, or Irregular Powders</i>									
53	0.18	170	123	3,130	59	1,250			
42	0.19	70	133	5,720	107	1,250 (P_{max}), 1,000 (dP/dt_{max})			
32	0.34	60	142	7,950	149	1,250	10		
32	0.58	65	133	8,880	167	750 (P_{max}), 1,500 (dP/dt_{max})	11	Ignition @ 8.0% Nonignition @ 7.5%	1,000
30	0.10	60					10		
28	0.11	55	140	6,360	119	1,000 (P_{max}), 1,250 (dP/dt_{max})	11		
28	0.21	55	146	8,374	157	1,500	11		
9	0.90	65	165	15,370	288	750 (P_{max}), 1,000 (dP/dt_{max})	4		
7	0.74	90	153	17,702	332	1,000 (P_{max}), 500 (dP/dt_{max})	12		
6	0.15	80	176	15,580	292	750	3.5		
6	0.70	75	174	15,690	294	500 (P_{max}), 1,000 (dP/dt_{max})	3		
5	1.00	70					4		
4	0.78	75	167	15,480	291	1,000 (P_{max}), 750 (dP/dt_{max})	3.5		
<i>Spherical Powders</i>									
63	0.15	120	101	1,220	23	1,250 (P_{max}), 1,000 (dP/dt_{max})	N.I.	Ignition @ 1 8.0% Nonignition @ 7.5%	1,750
36	0.25	60	124	4,770	90	1,250	13		
30	0.10	60	140	5,940	111	1,000	13		
15	0.50	45	148	10,812	203	1,000	7		
15	0.30	55					8		
6	0.53	75	174	16,324	306	750	6		
5	1.30		167	14,310	269	750		Ignition @ 6.0% Nonignition @ 5.5%	750
5	1.00	70	155	14,730	276	1,250	6	Ignition @ 6.0% Nonignition @ 5.5%	1,250
3	2.50	95	165	15,900	298	1,250	4		
2	3.00	130							

For U.S. conversions: $1 \text{ m}^2/\text{g} = 4884 \text{ ft}^2/\text{lb}$; $1 \text{ g}/\text{m}^3 = 0.000062 \text{ lb}/\text{ft}^3$; $1 \text{ bar}/\text{sec} = 14.5 \text{ psi}/\text{sec}$; $1 \text{ bar}\cdot\text{m}/\text{sec} = 0.226 \text{ psi}\cdot\text{ft}/\text{sec}$.

BET: surface area per unit mass; MEC: minimum explosible concentration; MIE: minimum ignition energy; LOC: limiting oxygen (O_2) concentration.

Notes:

- (1) The powders tested are representative samples produced by various manufacturers utilizing a variety of methods of manufacture, submitted for testing to a single, nationally recognized testing laboratory, at the same time.
- (2) Data for each characteristic were obtained using the following ASTM methods: MEC: ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*; MIE: ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*; maximum pressure rise (P_{max}), maximum pressure rise rate (dP/dt), and deflagration index (K_{st}): ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*; LOC: ASTM E2079, *Standard Test Methods for Limiting Oxygen (Oxidant) Concentration in Gases and Vapors*.
- (3) Particle size data represent the d_{50} measurement determined by the laser light-scattering technique.
- (4) Test results represent only the characteristics of those samples tested and should not be considered to be universally applicable. Users are encouraged to test samples of powders obtained from their individual process.
- (5) The determination of explosibility parameters (i.e., P_{max} , LOC, K_{st}) for nanometals should be conducted with representative nanometal samples, because the values of some explosibility parameters can be significantly different than the corresponding values measured with micrometer-sized samples. In the case of many nanometals, the ASTM E1226 test methods to determine explosibility parameters require modification to prevent pre-ignition during compressed air injection into the test vessel. (See Bouillard 2010 and Boilard 2013.)

The test regimen employs a 20 L or larger spherical explosion chamber. A sample of the test powder is injected into the sphere using air driven at a force of 20 bar. Ignition is accomplished via the use of two 5 kJ chemical igniters. The test enclosure is partially evacuated so that at the end of the injection, the dust cloud is at atmospheric pressure. The pressure–time history of the explosion event is measured for each test, and the maximum explosion pressure (P_{\max}) and the maximum rate of pressure rise (dP/dt_{\max}) are determined. A series of these tests are conducted over a wide range of dust concentrations, and the individual maximum values measured are called P_{\max} and dP/dt_{\max} . The critical tests are performed in triplicate, and the values obtained at the optimum dust concentration are then averaged to obtain P_{\max} and dP/dt_{\max} . In general, these two concentrations are not the same. The value at which P_{\max} occurs is c_{opt} , and the value at which dP/dt_{\max} occurs is c_w . In this document, c_w is used to evaluate dust explosion hazard and dust flash-fire hazard areas.

From the data for the dP/dt_{\max} , the value of K_{St} is calculated. The K_{St} value allows different materials to be compared on an equal basis to determine a relative ranking of explosion risk and consequence. The K_{St} value is obtained by normalizing the maximum value of dP/dt_{\max} to a volume of 1 m³. Materials are classified according to the *St* class system in Table A.5.4.4. The higher a powder *St* class number, the more energetic the explosion and the greater the speed of the explosion.

Limiting Oxidant Concentration (LOC) Test. The purpose of the test is to determine the oxygen concentration below which the ignition of the dispersed dust is not possible.

The test is conducted in accordance with ASTM E2931, *Standard Test Method for Limiting Oxygen (Oxidant) Concentration of Combustible Dust Clouds*, or EN 14034-4, *Determination of Explosion Characteristics of Dust Clouds – Part 4: Determination of the Limiting Oxygen Concentration (LOC) of Dust Clouds*.

The LOC test is conducted using a 20 L or larger spherical explosion chamber described for the explosibility test.

The protocol for the LOC test requires pursuing an algorithm for the simultaneous search for the lowest oxygen concentration that can support self-sustaining flame propagation, and the optimum powder concentration at the lowest oxygen concentration. Tests are repeated with lower and lower oxygen concentrations (percent by volume) until the lowest level of oxygen capable of supporting explosion is determined.

The “break” point definition of what is and what is not an explosion event has changed over the last decade. Current ASTM and EN standards define an ignition as a measured value of pressure during the test that is equal to or greater than 1 bar-g. The results can be quite sensitive to the choice of this threshold value especially in smaller test enclosures.

Minimum Explosible Concentration (MEC) Test. The test to determine the MEC of a combustible dust is performed using ASTM E1515, *Test Method for Minimum Explosible Concentration of Combustible Dusts*, or EN 14034-3, *Determination of Explosion Characteristics of Dust Clouds – Part 3: Determination of the Lower Explosion Limit (LEL) of Dust Clouds*.

The test is performed using the 20 L or larger spherical explosion chamber. Testing is performed to determine a nominal dust concentration at which ignition always occurs. The dust concentration is then reduced until no evidence of igni-

tion is found. The threshold-defining point for this test between ignition and no-ignition is a pressure rise of 1 bar-g.

The MEC test is critical for determining the dust loading of dust collection systems as well as determining when fugitive dust accumulation has reached a point where explosion danger is manifest.

A.5.5.1 Tests of representative samples are preferred. Historical data can be used but require an assessment of data to determine if they are truly representative of the material being analyzed.

A.5.5.2 Examples of properties that should be assessed are as follows:

- (1) Composition
 - (a) Pure materials
 - (b) Mixtures (including diluents or grinding media)
 - (c) Treatment such as oxidation
 - (d) Aging
- (2) Form
 - (a) Particle size
 - (b) Morphology (angular, acicular, spherical, fiber, irregular, agglomerate)
- (3) Distribution
 - (a) Friability of solids and particle attrition through the process
 - (b) Particle agglomeration influences including morphology and moisture content

A.5.6 The flash fire potential of a metal particulate sample should be assessed using the screening test methodology described in Section 13 of ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*. If the explosibility screening tests conducted in accordance with ASTM E1226 produces an explosion pressure ratio greater than two, the test material should be considered to have a flash fire potential.

▲ **A.6.1.3** Chapter 5 of NFPA 101 provides a more complete description of the performance-based design process and requirements. In addition, the SFPE *Engineering Guide to Performance-Based Fire Protection* outlines a process for developing, evaluating, and documenting performance-based designs.

A.6.1.4 Relevant aspects that could require a re-evaluation include, but are not limited to, changes to the following:

- (1) Information about the hazardous characteristics of the materials
- (2) Information about the performance capabilities of protective systems
- (3) Heretofore unrecognized hazards

Intentional changes to process materials, technology, equipment, procedures, and facilities are controlled by section by sections pertaining to management of change.

Table A.5.4.4 Explosive Energy Classification

<i>St</i> Class	K_{St} (bar-m/sec ⁻¹)
<i>St</i> 1	>0–200
<i>St</i> 2	201–300
<i>St</i> 3	>300

A.6.2.3 Other stakeholders could also have mission continuity goals that will necessitate more stringent objectives as well as more specific and demanding performance criteria. The protection of property beyond maintaining structural integrity long enough to escape is actually a mission continuity objective. The mission continuity objective encompasses the survival of both real property, such as the building, and the production equipment and inventory beyond the extinguishment of the fire. Traditionally, property protection objectives have addressed the impact of the fire on structural elements of a building as well as the equipment and contents inside a building. Mission continuity is concerned with the ability of a structure to perform its intended functions and with how that affects the structure's tenants. It often addresses post-fire smoke contamination, cleanup, replacement of damaged equipment or raw materials, and so forth.

A.6.2.4.1 Adjacent compartments are those sharing a common enclosure surface (wall, ceiling, floor) with the compartment of fire or explosion origin. The intent is to prevent the collapse of the structure during the fire or explosion.

A.6.3.5(3) Deflagration vent operation does not constitute rupture of the equipment.

A.6.4 The risk evaluation conducted according to Section 5.7 might be useful in identifying the design scenarios for Section 6.4.

The fire and explosion scenarios defined in Section 6.4 assume the presence of an ignition source, even those scenarios limited by administrative controls (such as a hot work permit program). It is the responsibility of the design professional to document any scenario that has been excluded on the basis of the absence of an ignition source.

A.6.4.1.1 A compartment is intended to include the area within fire-rated construction.

Δ A.6.5.1 The SFPE *Engineering Guide to Performance-Based Fire Protection* outlines a process for evaluating whether trial designs meet the performance criteria.

N A.7.1 Metals in a combustible form present three primary hazards, solids in combustible form (e.g., chips, swarf, fines, ribbon, solids or alkali metals), combustible metal dust, and combustible metal in a molten form.

N A.7.1.1 It is not always possible or practical for existing facilities to be in compliance retroactively with new provisions of a standard on the effective date of that standard. However, a plan should be developed to achieve compliance within a reasonable timeframe.

N A.7.2.1.3 One method by which the requirement in 7.2.1.3 can be satisfied is with a hazard analysis conducted in accordance with the methods outlined in *Guidelines for Hazard Evaluation Procedures*. To determine if a dust deflagration hazard exists, see Figure 5.4.1.

N A.7.2.2.1 NFPA standards rely on the determination of "where an explosion hazard or deflagration hazard exists." There are other physical and health hazards to consider such as toxicity, reactivity with water, and so forth that can be considered when conducting a DHA. The DHA should consider the four conditions that are required for a deflagration:

- (1) A combustible particulate solid of sufficiently small particle size to deflagrate

- (2) A combustible particulate solid suspended in air to deflagrate (or other oxidizing medium)
- (3) A combustion particulate solid suspension of sufficiently high concentration to deflagrate
- (4) A competent igniter applied to the suspension of combustible particulate solids where the concentration is sufficient for flame propagation. [652:A.7.2.1]

A deflagration leading to an explosion will occur whenever all four criteria occur within a compartment or container at the same time. Since gravity is a concentrating effect and we always assume an ignition source is present unless we can prove one cannot exist, even under conditions of equipment failure, this list reduces to:

- (1) A combustible particulate solid of sufficiently small particle size to deflagrate
- (2) A means for suspending the combustible particulate solid in air (or other oxidizing medium)
- (3) A sufficient concentration can be achieved [652:A.7.2.1]

Most dust explosions occur as a series of deflagrations leading to a series of explosions in stages. While a single explosion is possible, it is the exception rather than the rule. Most injuries are the result of the "secondary" deflagrations rather than the initial event. Most "explosion" events are a series of deflagrations each causing a portion of the process or facility to explode. Primary deflagrations lead to secondary deflagrations, usually fueled by accumulated fugitive dust that has been suspended by the following:

- (1) Acoustic impulse waves of the initial, primary, deflagration
- (2) Entrainment by deflagration pressure front [652:A.7.2.1]

The majority of the property damage and personnel injury is due to the fugitive dust accumulations within the building or process compartment. The elimination of accumulated fugitive dust is CRITICAL and the single most important criterion for a safe workplace. [652:A.7.2.1]

N A.7.2.2.2 The qualified person who is leading or performing the DHA should be familiar with conducting a DHA. The qualified person should also be familiar with the hazards of combustible metals. Typically, a team performs a DHA. For some processes this team can be as few as two persons, or for larger and more complex processes, the team might require more than two persons. This team is made of a variety of persons whose background and expertise can include the following:

- (1) Familiarity with the process
- (2) Operations and maintenance
- (3) Process equipment
- (4) Safety systems
- (5) History of operation
- (6) The properties of the material
- (7) Emergency procedures

[652:A.7.2.2]

The individuals involved in the DHA could include facility operators, engineers, owners, equipment manufacturers, or consultants. [652:A.7.2.2]

N A.7.2.3.1(2)(b) The hazard management document for all the areas of the process or facility compartment determined to be combustible dust hazards should include, but not be limited to, the following:

- (1) Test reports
- (2) Drawings
- (3) Sizing calculations

[652:A.7.3.1(2)(b)]

Paragraph 7.2.3.1 outlines the minimum steps of a dust hazards analysis. [652:A.7.3.1(2)(b)]

N A.7.2.3.3.1 This includes the process systems and ancillary equipment such as dust collection systems. Where multiple compartments present essentially the same hazard, a single evaluation might be appropriate. [652:A.7.3.3.1]

N A.7.2.3.3.3 Each and every process component should be evaluated, including ducts, conveyors, silos, bunkers, vessels, fans, and other pieces of process equipment. Each point along the process should be described, and hazards at each point should be identified. Remedial measures for each hazard should be identified and documented. The means by which the hazard should be managed is then determined. The process and process equipment will often determine which option is most appropriate. (*See Annex B of NFPA 652 for an example of a process hazard analysis.*)

N A.7.2.3.4.2 Each and every facility compartment containing combustible metal particulate solids should be evaluated. The complete contents of the compartment should be considered, including hidden areas. Each area in the compartment should be described, and hazards at each point should be identified. Remedial measures for each hazard should be identified and documented. The means by which the hazard should be managed is then determined.

N A.7.3.2.2 See A.7.2.2.2.

N A.7.3.3.1(2)(b) See A.7.2.3.1(b).

N A.7.3.3.3.1 See A.7.2.3.3.1.

N A.7.3.3.3.3 See A.7.2.3.3.1.

A.8.2.3 Molten metal and molten metal chloride present an extremely dangerous fire and fume hazard, in addition to an explosion hazard, if contacted with water or residual moisture.

A.8.3.1.1 Sprinkler systems in buildings or portions of buildings where combustible metals are produced, handled, or stored pose a serious risk for explosion. When water is applied to most burning combustible metals, hydrogen gas can be generated. When confined in an enclosed space, dangerous levels of hydrogen gas can collect and result in the potential for a hydrogen explosion. The metal will likely spread and spew burning material.

A.8.3.1.2 Iron and steel are examples of combustible metals where sprinkler protection could be considered. Automatic sprinkler protection is not recommended for buildings that contain blending and melting operations.

Δ A.8.3.1.6 A slow-burning fire in nearby combustible material can develop enough heat to ignite thin-section metal and produce a well-involved metal fire before automatic sprinklers operate. Special importance, therefore, should be attached to prompt fire detection and alarm service, design of a fast-

operating automatic sprinkler system, and avoidance of obstructions to sprinkler discharge. See NFPA 13.

A.8.3.2.1 The reaction of alkali metals, especially burning alkali metals, with water is extremely hazardous. Where combustible loading in areas used for alkali metals processing is determined by the authority having jurisdiction to require sprinkler protection, consideration should be given to the installation of preaction sprinkler systems to reduce the opportunity for accidental discharge.

Where the presence of non-water-reactive, combustible materials has been determined to require sprinkler protection, the quantities of alkali metals exposed to sprinkler action and the ability of workers to quickly secure the exposed alkali metals (e.g., place the lid back on the drum to reseal the container) also need to be evaluated.

Δ A.8.3.2.6 See NFPA 499.

A.8.3.3 Table A.8.3.3 provides information on recommended extinguishing agents.

Experience has shown that sodium chloride is one of the most effective chemicals for containing fires involving combustible-metal powder. Fire-fighting salts should be checked on a regular basis (such as weekly or monthly) to ensure that they have not absorbed moisture (usually evidenced by caking). If damp salt is applied to a combustible-metal fire, the intense heat will flash the moisture to steam in an explosive manner.

Various commercial fire extinguishers are available with agents approved for combustible-metal fires. When using any approved agent, it is important to completely cover the burning material, thus reducing the oxygen supply and slowing the burn rate until the fire is extinguished. If the agent is removed from the burning material too early, re-ignition can occur.

A.8.3.3.1 Dry sodium chloride or other dry chemical compounds suitable for extinguishing or containing combustible-metal fires can be used as substitutes for Class D fire extinguishers.

Class B extinguishing agents will usually greatly accelerate combustible-metal fires and can cause the burning metal to explode.

A.8.3.3.5(5) Nitrogen can be considered as an extinguishing agent for iron, steel, and many alkali metals. Gaseous nitrogen is not a suitable extinguishing agent for lithium. Some nitrogen-argon blends have been shown to be an effective extinguishing agent for some combustible metals.

A.8.3.3.9 Recent experience has shown that some types of water-based foam extinguishing agents can be effective on solvent fires.

A.8.3.3.9.2.1 Milling of aluminum with combustible solvents is practiced in the manufacture of aluminum flake used in pigments and powders. The material is handled as a slurry during processing. Some of the product is marketed as a paste; other portions are filtered, dried, sometimes polished, and sold as dry flake powder. The solvents employed are generally moderately high-flash-point naphthas. A fire in an aluminum powder slurry is primarily a solvent fire and can be fought using Class B extinguishing agents, except for halogenated extinguishing agents.

Table A.8.3.3 Combustible Metal Fire-Extinguishing Agents Quick Reference Chart

Extinguishing Agents	Metals								
	Alkali Metals (Calcium, NaK, Sodium)	Lithium	Aluminum	Iron and Steel	Magnesium	Niobium	Tantalum	Titanium	Zirconium
Coke (carbon microspheroids)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Met-L-X	Yes*	No	Yes*	Yes	Yes*	Yes*	Yes*	Yes*	Yes*
Lith-X	Yes*	Yes*	No	No	No	No	No	No	No
Copper powder	Yes*	Yes*	Yes	No	No	No	No	No	No
Dry flux	Yes	Yes	Yes*	No	Yes*	No	No	No	No
Dry sand	Yes	Yes	Yes*	Yes	Yes*	Yes*	Yes*	Yes*	Yes*
Dry lithium chloride	Yes	Yes	No	No	No	No	No	Yes	Yes
Dry soda ash	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes
Dry sodium chloride	Yes	Yes	Yes*	No	Yes*	Yes*	Yes*	Yes*	Yes*
Water	No	No	No	Yes	No	No	No	No	No
Foam	No	No	No†	Yes	No	No	No	No	No
Argon	Yes*	Yes	Yes*	Yes	Yes*	Yes*	Yes*	Yes*	Yes*
CO ₂	No	No	No	No	No	No	No	No	No
Nitrogen	Yes*	No	No	Yes	No	No	No	No	No
Halon	No	No	No	No	No	No	No	No	No
Hydrocarbon Clean Agent	No	No	No	No	No	No	No	No	No

Note: When combustible metals are blended with other materials, the extinguishing agent should be compatible with the combustible metal.

*Preferred extinguishing agent.

†Aqueous film forming foam (AFFF) has been shown to be effective on aluminum paste fires in the incipient stage where a Class B solvent is the primary fuel.

Major producers usually employ fixed extinguishing systems of carbon dioxide or foam in this area. Some Class B portable extinguishers also are provided. Obviously, judgment should be used in determining whether Class B extinguishing agents can be used safely. If the extinguishing agent is carefully applied, it will be evident if it accelerates the fire. If the agent does accelerate the fire, its use should be discontinued, and a dry, inert granular material should be used. A fire in filter cake, a solvent-wetted but semi-dry material containing aluminum, can be a solvent fire or it can, at some point, exhibit the characteristics of a powder fire, at which time it should be treated as such. If the aluminum metal has ignited, it can continue to burn under a crust without flames.

A.8.3.3.9.2.2 Re-ignition can occur due to high localized heat or spontaneous heating. To avoid re-ignition, the residual material should be immediately smothered.

A.8.3.3.10.1 The use of fine, dry sand, preferably less than 20 mesh, or other approved powder is an effective method of isolating incipient fires in combustible-metal dust. An ample supply of such material should be kept in covered bins or receptacles located in the operating areas where it can be reached at all times. A long-handled shovel of spark-resistant metal should be provided at each such receptacle to afford a ready means of laying the material around the perimeter of the fire.

Nearly all vaporizing liquid-fire-extinguishing agents react violently with burning combustible metal, usually serving to greatly intensify the fire and sometimes resulting in explosion.

Water hose streams should not be used. The impact of the water stream can lift enough dust into the air to produce a

strong dust explosion. In addition, water reacting with aluminum can give off highly flammable hydrogen gas.

A.8.3.3.10.3 Application of wet extinguishing agents accelerates a combustible metal fire and could result in an explosion.

The application of pressurized extinguishing agents should be performed only by trained personnel because of the danger of spreading the burning powder or chips or creating a dust cloud.

Bulk dry extinguishing agents should be provided in areas where chips and powders are produced or used and should be kept dry (i.e., free of moisture).

A.8.3.4.1 Where employees are expected to conduct any type of fire-fighting operations, the employees should receive training on a regular basis. Additional eye protection should be considered for personnel expected to fight a fire to protect against the higher degree of emitted light from the burning combustible metals.

A.8.3.4.8.1 Keeping the equipment in operation until all burning material is removed can reduce damage to the equipment. Small amounts of burning materials can be handled with a shovel to facilitate removal.

A.8.3.4.9.1 One of the greatest dangers to fire fighters is the splattering effect of burning alkali metals. Molten alkali metal is very fluid and easily spread; therefore, extreme care needs to be taken when applying fire-fighting agent. The force used to deliver agent from an extinguisher can cause the molten alkali to splash to adjacent areas. Therefore, the delivery technique is very important. If direct agent application becomes hazardous, indirect application techniques should be used. Deflecting

agent off another object or directing the agent stream above the hazard and letting the agent fall by gravity can be effective.

A.8.3.4.9.2 Forming a crust over burning alkali metals reduces the available oxygen and eliminates exothermic reactions. Extinguishing agent should first be applied to the white-hot burning areas, then evenly applied to the mass, controlling the flow to form an oxygen-depleting crust. Since alkali metal tends to flow easily through any weak spots, agents should be applied evenly to construct a continuous crust. If the alkali metal surfaces, additional agent should be applied to strengthen the crust.

Actual crust formation is created by the ability of some powdered agents to absorb heat from the alkali metals. In the case of copper powder, an alkali metal–copper alloy is formed as heat is absorbed from an alkali metal. Once the crust is formed, the temperature of the alkali metal decreases and exothermic reactions are reduced. Extreme care should be taken to ensure that the crust is not disturbed or broken until the temperature of the alkali metal is decreased to the point where resolidification occurs (or in the case of NaK, until the mass is at or near room temperature).

A.8.3.5.2.2 It is recommended that a practice fire drill be conducted once each year to familiarize local fire department personnel with the proper methods of fighting Class D fires. Professional or volunteer fire fighters from outside the plant cannot be expected to be trained for the specific fire and life hazards associated with metal powder and fires. In the interest of their own safety, they should be directed by the plant's safety officer or fire-fighting officer.

A.8.4.2 Employee health and safety in operations depend on the recognition of actual or potential hazards, the control or elimination of those hazards, and the training of employees on safe working procedures.

A.8.4.4 Emergency preparedness plans for alkali metals should pay special attention to the extreme hazards associated with alkali metals–water reactions that might occur with sprinkler water. Specific attention should be paid to an evacuation plan for personnel in the event of any release of water.

The particulate fumes given off by burning alkali metals are very corrosive; therefore, nonessential personnel in the vicinity should be evacuated to a safe distance, with special attention given to shifting winds. Where frequent alkali metals fires can affect local environmental quality conditions, an exhaust treatment system should be provided.

Properly trained personnel who work with alkali metals know its hazards. Such personnel will have the greatest chance to extinguish an alkali-metal fire in its incipient stage. Training should include sufficient information to determine whether extinguishment can be accomplished safely and effectively.

An alkali metal at room temperature in the presence of incompatible materials can reach its melting point and its autoignition temperature.

The degree of reaction and the amount of time to produce the melting point and autoignition temperature vary with conditions surrounding the fire, with the temperature of the exposed alkali metals being the major factor. At low temperatures or temperatures within a few degrees of an alkali metal's melting point, the reaction is slower with reduced intensity. At higher temperatures, the reaction is accelerated and more intense.

When fighting an alkali-metals fire, it is very important that fire fighters be aware of the dangers of burning alkali metals. When molten alkali metal reacts with materials such as water or flammable or combustible liquids or gases, molten alkali metals can be ejected for a considerable distance. The severity of alkali-metal reactions varies with a multitude of conditions.

Residues of alkali metals that have been in contact with moisture and air are alkali-metal hydroxides and alkali-metal oxides, which will cause caustic burns when in contact with the skin or eyes. Personnel must wear adequate caustic-resistant PPE when handling residues from alkali metal fires.

A.8.4.7 Fire blankets have been found to be effective for extinguishing clothing fires. They should be distributed in plant areas where water is excluded.

A.8.5 The objectives in fighting combustible metal fires are isolation and containment, rather than extinguishment. Water and other liquids have proved ineffective in extinguishing combustible metal fires. Streams of water intensify most combustible metal fires by feeding it oxygen. There is also the possibility of causing a steam or hydrogen explosion, particularly if large amounts of combustible metal are involved. The great affinity of high-temperature combustible metal for oxygen frees a considerable amount of hydrogen, which can reach explosive concentrations in confined spaces. Entrapment of water under any burning or hot combustible metal can result in a steam explosion.

Because of their unique nature, combustible metal fires demand a comprehensive fire protection plan wherever combustible metal is processed, handled, used, or stored. This plan should include specific actions in the event of a combustible metal fire and should be coordinated with the local facility management, responding fire fighters, and medical personnel.

The plan should recognize the extreme hazards associated with combustible metal–water reactions that might occur with sprinkler water. Specific attention should be given to an evacuation plan for personnel in the event of any release of water.

Properly trained personnel who work with combustible metal know its hazards. Such personnel are best equipped to extinguish a combustible metal fire in its incipient stage. Training should include sufficient information to determine whether extinguishment can be accomplished safely and effectively.

A.8.5.1(1) The physical state of the product, such as chips, powder, fines, and dust, and the quantity of product involved in the fire, potentially involved in the fire, or both, are extremely important factors for emergency responders.

A.8.5.1(13) Fires involving large quantities of product within structures can result in rapid heat buildup and smoke generation beyond that normally encountered in fires involving ordinary combustibles.

Δ A.9.3 Items that should be included in the housekeeping plan include, but are not limited to, the following:

- (1) A risk analysis that considers the specific characteristics of the dust being cleaned (particle size, moisture content, MEC, MIE) and other safety risks introduced by the cleaning methods used
- (2) Personal safety procedures, including fall protection when working at heights

- (3) Personal protective equipment (PPE), including flame-resistant garments and the need for static-dissipative shoes in accordance with the hazard analysis required by NFPA 2113
- (4) Cleaning sequence
- (5) Cleaning methods to be used
- (6) Equipment, including lifts, vacuum systems, attachments, etc.

A.9.4.1 Once ignition has occurred either in a cloud suspension or in a layer, an explosion is likely. Often the initial explosion is followed by another much more violent explosion, fueled by the dust from accumulations on structural beams and equipment surfaces that is thrown into suspension by the initial blast. For that reason, good housekeeping in all areas that handle dust is vitally important.

A.9.4.2 There have been several proposed methods for determining an appropriate threshold value for fugitive dust accumulations. It should be noted that some methods might not be appropriate in all situations.

A.9.5 Unscheduled housekeeping should be performed in accordance with Table A.9.5(a) to limit the time that a local spill or short-term accumulation of dust is allowed to remain before cleaning the local area to less than the threshold dust mass/accumulation.

Table A.9.5(b) shows approximate equivalent depths for the accumulation values in Table A.9.5(b) when the threshold dust mass/accumulation is 1 kg/m². The owner/operator can use an approximate depth to facilitate communication of housekeeping needs.

A.9.6 Permanently installed vacuum cleaning systems provide the maximum safety because the dust-collecting device and the exhaust blower can be located in a safe location outside the dust-producing area.

▲ **A.9.6.2** See NFPA 77.

A.9.6.3 Utility vacuums or residential, automotive, hobby, or household portable vacuums should not be used.

▲ **A.9.6.4** It is recommended that no more than 2.2 kg (5 lb) of dust should be collected at any one time before being emptied. A vacuum cleaner should be checked to be sure that it is empty before each use. A vacuum cleaner should be emptied at the end of each use.

Improper use of vacuum cleaners for combustible metal powder accumulations can result in fire or explosion. For information on static electricity, see NFPA 77.

A.9.6.5 For example, iron oxide dusts are known to be incompatible with titanium, aluminum, magnesium, and other metal dusts due to the potential for an exothermic thermite reaction (see A.3.3.74 for additional information). The dust-separating unit should be cleaned unless it has been determined that the materials exhibit no incompatibility.

A.9.9.1 A relatively small initial dust explosion will disturb, and suspend in air, dust that has been allowed to accumulate on the flat surfaces of a building or equipment. This dust cloud provides fuel for the secondary explosion, which usually causes the major portion of the damage. Reducing dust accumulations is, therefore, a major factor in reducing the hazard in areas where a dust hazard can exist.

Where the underlying surface color is no longer discernible beneath the accumulated dust layer, this can be sufficient to warrant immediate cleaning of the area. Dust accumulation on overhead beams and joists contributes significantly to the secondary dust cloud. Other surfaces, such as the tops of ducts and large equipment, can also contribute significantly to the dust cloud potential. Consideration should be given to dust that adheres to walls, because it is easily dislodged.

Attention and consideration should also be given to other projections, such as light fixtures, that can provide surfaces for dust accumulation.

Table A.9.5(a) Examples of Unscheduled Housekeeping

Accumulation on the Worst Single Square Meter of Surface	Longest Time to Complete Unscheduled Local Cleaning of Floor-Accessible Surfaces	Longest Time to Complete Unscheduled Local Cleaning of Remote Surfaces
>1 to 2 times threshold dust mass/accumulation	8 hours	24 hours
>2 to 4 times threshold dust mass/accumulation	4 hours	12 hours
>4 times threshold dust mass/accumulation	1 hour	3 hours

Table A.9.5(b) Examples of Unscheduled Housekeeping

Accumulation on the Worst Single Square Meter of Surface		Average Depth at 75 lb/ft ³		Average Depth at 30 lb/ft ³	
kg/m ²	lb/ft ²	mm	in.	mm	in.
>1 to 2	>0.2–0.4	0.8–1.7	>1/32–1/16	2.1–4.2	>5/64–5/32
>2 to 4	0.4–1.6	1.7–3.3	>1/16–1/8	4.2–8.3	>5/32–5/16
>4	1.6	>3.3	>1/8	>8.3	>5/16

A.9.9.3 Factors that should be considered in establishing the housekeeping frequency include the following:

- (1) Variability of fugitive dust emissions
- (2) Impact of process changes and non-routine activities
- (3) Variability of accumulations on different surfaces within the room (walls, floors, overheads)

A.10.1 It is not always possible or practical for existing facilities to be in compliance with new provisions of a standard on the effective date of that standard. Therefore, retroactivity in this section means that a plan to achieve compliance within a reasonable time frame should be established.

A.10.2 Attention is called to the hazardous conditions that could exist both inside and outside the plant if cutting torches are used to dismantle dust collectors or powder-producing machinery before all dust accumulations have been removed.

It is a commonly recognized practice that operators of cutting or welding torches be required to obtain a written permit from the safety or fire protection officer of the plant before using their equipment under any condition around metal powder plants.

A.10.3.1 Separation distances between a designated smoking area and areas where combustible metals are present are defined through a hazards analysis.

A.10.4.1 A hybrid mixture can be present when handling metals in a combustible form either due to generation of hydrogen through the reaction of moisture or by intentional presence of solvents during milling operations. Even when the metal has an MIE of greater than 30 mJ, the hybrid mixture MIE can be less than 30 mJ. The concern is for impact sparks as well as electrostatic discharge.

A.10.4.2 Under certain circumstances, such as impacts with rusted iron or steel, aluminum cannot safely be considered to be nonsparking, since a minor thermite reaction can be initiated. For details, refer to Eisner, "Aluminum and the Gas Ignition Risk," and Gibson et al., "Fire Hazards in Chemical Plants from Friction Sparks Involving the Thermite Reaction."

Bonded and grounding of hand tools most often occurs through the person handling the tools. The use of insulating gloves or shoes could interrupt this grounding and bonding path.

A.10.5 Under certain circumstances, such as impacts with rusted iron or steel, aluminum cannot safely be considered to be nonsparking, since a minor thermite reaction can be initiated. For details, refer to Eisner, "Aluminum and the Gas Ignition Risk," and Gibson et al., "Fire Hazards in Chemical Plants from Friction Sparks Involving the Thermite Reaction."

A.10.5.1 In complex installations of machinery and equipment, the danger of the occurrence of an isolated conductor is possible. Therefore, it is highly recommended that bonding as well as grounding of permanently installed equipment be practiced. Redundant grounding and bonding provide a means of further eliminating this potential danger. NFPA 77 provides guidance on how to ground and bond equipment.

N A.10.5.1.2 Examples are gaskets between ductwork sections, and flexible hoses.

A.10.5.2 Portable processing equipment should be constructed in such a fashion that grounding can be readily accomplished. For instance, metal carts should have static-dissipative

wheels. Even with antistatic wheels, it is good practice to ground portable processing equipment with an external ground wire. Dirt and other material can coat the wheels, which could isolate the cart from the ground provided from static-dissipative floors. Additional attention should be given to bonding of portable equipment to eliminate the dangers of isolated conductors. Special attention should also be given to painted or coated equipment to ensure that the bonding connection provides continuity.

Δ A.10.5.3 It is recommended that a periodic test program be instituted to monitor the level of resistance to earth ground as well as to ensure that the integrity of fixed grounds remains acceptable. The need to ensure that grounding criteria are satisfied becomes more urgent as finer particle-sized material is processed. As always, it is recommended that a hazards analysis be conducted to ensure that bonding and grounding protocols match the sensitivity of the actual powders being processed.

Δ A.10.5.6 NFPA 77 provides guidance on how to ground personnel. The most common methods of personnel grounding are through conductive flooring and footwear or through dedicated personnel-grounding devices such as wrist straps. Grounding devices should provide a resistance to ground between 10^6 and 10^8 ohms. The lower resistance limit (10^6 ohms) is specified to protect personnel from electrocution due to inadvertent contact with energized electrical equipment, while the upper resistance limit (10^8 ohms) is specified to ensure adequate charge dissipation. Grounding devices should be tested regularly, and cleaning should be performed to ensure that accumulations of noncombustible residues do not interfere with continuity.

A.10.5.6.2(1) A hybrid mixture can be present when handling metals in a combustible form either due to generation of hydrogen through the reaction of moisture or by intentional presence of solvents during milling operations. Even when the metal has an MIE of greater than 30 mJ, the hybrid mixture MIE can be less than 30 mJ.

A.10.5.6.2(2) Based on information found in *Avoiding Static Ignition Hazards in Chemical Operations*, the maximum reasonable discharge energy from a person is estimated to be approximately 25 mJ. Where the MIE of the dust cloud is greater than 30 mJ, personnel grounding provides no risk reduction. MIE is dependent on particle size, so it is important to determine the MIE value on the particle size distribution that is likely to remain airborne during the operation. Since large particles will quickly fall out of suspension, the sub-75 micron fraction of the material (or material passing through a 200-mesh sieve) is typically tested for this purpose. Where a bulk material includes larger particles, the sub-75 micron MIE might be significantly lower than the bulk material MIE. ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, is the test method for determining particulate and dust MIE.

A.10.6.2.2 Information on spark-resistant fans and blowers can be found in AMCA Standard No. 99-0401, "Classifications for Spark Resistant Construction."

A.10.6.2.4 Fans or blowers can also be provided with vibration indicating devices, arranged to sound an alarm, to provide shutdown, or both, in the event of blade or rotor imbalance, or bearing or drive problems.

A.10.6.3 Special precautions are necessary to prevent ignitions during dressing of the wheels used for grinding combustible

metal castings. Hot metal thrown off by the dressing tool can ignite dust or deposits in the hood or duct.

▲ **A.10.8.1** Housekeeping can reduce or eliminate the electrical area classification for a location where combustible metal dust is present. Electrical equipment upgrades to meet Article 500 of *NFPA 70* can be costly and users might better focus on preventing fugitive dust from escaping equipment and accumulations to minimize the extent of the hazardous (classified) areas.

A.10.8.4 Finding combustible metal dust or powder within electrical equipment and components should warrant more frequent inspection and cleaning.

▲ **A.10.9.2** Diesel-powered, front-end loaders suitable for use in hazardous (classified) locations have not been commercially available. The following provisions can be used to reduce the fire hazard from diesel-powered, front-end loaders used in combustible dust areas, as defined in Articles 500 and 506 of *NFPA 70*:

- (1) Only essential electrical equipment should be used, and wiring should be in a metal conduit. Air-operated starting is preferred, but batteries are permitted to be used if they are mounted in enclosures rated for Type EX hazardous areas.
- (2) Where practical, a water-cooled manifold and muffler should be used.
- (3) Loaders that are certified to meet the Mine Safety and Health Administration (MSHA) criteria (formerly Schedule 31) found in 30 CFR 36, "Approved Requirements for Permissible Mobile Diesel-Powered Transportation Equipment," are also acceptable in lieu of A.10.9.2(1) and A.10.9.2(2).
- (4) The engine and hydraulic oil compartments should be protected with fixed, automatic dry-chemical extinguishing systems.
- (5) Loaders should have a high degree of maintenance and cleaning. Frequent cleaning (daily in some cases) of the engine compartment with compressed air could be necessary. Periodic steam cleaning also should be done.
- (6) Loaders should never be parked or left unattended in the dust explosion hazard or dust fire hazard area.

A.10.10.1 The use of propellant-actuated tools presents several potential ignition source hazards, including the possibility of impact or friction spark generation, as well as the ignition of a propellant during use. All areas where such tools may be used should be thoroughly cleaned of any accumulation of metals in a combustible form and use should be strictly controlled under the facility hot work program.

● **A.11.2** The following are the two generally recognized methods of separating combustible metal dust in industrial dust collection systems:

- (1) Wet-type air-material separator (AMS) that uses liquid for air-material separation and that is located indoors near the point of dust generation
- (2) Dry-type AMS that uses filter bags or cartridge media for air-material separation and that should be located outdoors as close as possible to the point of dust generation

A dry-type AMS is not recommended for niobium or tantalum dust. There are some specialized applications where an indoor dry-type AMS can be used for the collection of metal

dusts when a wet-type AMS or an outdoor dry-type AMS are not feasible.

Dust collection systems use air or inert gases (rare but feasible conditions) to convey combustible dusts from one location to another, a process that is similar to that of pneumatic conveying/transfer and centralized vacuum cleaning systems. However, dust collection system design uses design parameters that are significantly different from pneumatic conveying/transfer and centralized vacuum cleaning systems. For example, a typical dust collection system does not consider dust loading in the design calculations because the mass of air or gas is much greater than the collected dust particle mass loading. However, pneumatic conveying/transfer and centralized vacuum cleaning systems must consider the expected material mass loading in the design calculations.

Compared to typical dust collection systems and centralized vacuum cleaning systems handling combustible dusts, typical dilute and dense phase pneumatic conveying systems represent a significantly lower deflagration risk, assuming proper design and operation.

For guidance on the designing, acquisition, operation, and maintenance of dust collection systems, refer to the ACGIH publication, *Industrial Ventilation — A Manual of Recommended Practice for Design*, and A.11.2.3.4.

■ **A.11.2.1** This chapter covers requirements for dust collection systems intended to convey and collect fugitive dust. Generally, fugitive dust is created by machining, fabricating, finishing, bulk-handling, and other dust-generating operations or consists of powder that have escaped from a process. Powders are particles of matter intentionally manufactured to a specific size and shape and are typically handled in processing equipment systems.

■ **A.11.2.3.2** The system information and documentation should include the following:

- (1) System design specifications
- (2) System installation specifications
- (3) Equipment specifications
- (4) Operational description
- (5) System deflagration protection and specifications, including explosibility information
- (6) System mechanical and electrical drawings
- (7) System controls and specifications

The design of the dust collection system should be coordinated with the architectural and structural designs of the areas involved.

■ **A.11.2.3.3** Dust collection systems are designed for specific conveying, air distribution, and minimum duct velocity requirements. Changing any of those requirements can significantly change the ability of the system to provide the original design performance. An analysis of any proposed changes should be done to assure the system will still be able to perform as required to meet safety and operational requirements.

■ **A.11.2.3.4** Metal dusts or particles, due to their density, deflagration hazard, or both, require higher-than-normal conveying velocities to ensure adequate conveying velocities. Most applications should use 1372 m/min (4500 ft/min) or higher to maintain conveying velocities, especially for more complex systems, longer duct runs, and multiple turns. Abrasive wear must also be considered, so a maximum velocity in the 1676 to

1829 m/min (5500 to 6000 ft/min) range is typically recommended. Higher velocities also allow for unknown upset conditions but do require additional energy (i.e., static pressure) to achieve the desired results. Further information can be obtained by referring to the ACGIH publication, *Industrial Ventilation — A Manual of Recommended Practice for Design*.

N A.11.2.3.6.2 Proper dust collection design requires that a minimum air volume flow be maintained for each dust collection source point (hood). This value must be determined as part of the design process. This value should be documented to allow for field-testing to determine if the system is providing that flow and operating properly. [652:A.8.3.3.3.1]

This design also requires that the hood be constructed to assure that a continuous airflow is provided at all times. [652:A.8.3.3.3.1]

The ACGIH publication, *Industrial Ventilation — A Manual of Recommended Practice on Design*, has extensive information on the design basis for dust collection hoods and the necessary minimum air volumes and velocities to assure the containment, capture (i.e., collection), and control of the aerated dusts being generated. [652:A.8.3.3.3.1]

N A.11.2.3.6.3 Proper dust collection system design requires that a minimum air volume flow be maintained for each dust collection point source (i.e., hood). This value must be determined as part of the design process. This value should be documented to allow for field-testing to determine if the system is providing, at a minimum, the design flow and operating properly.

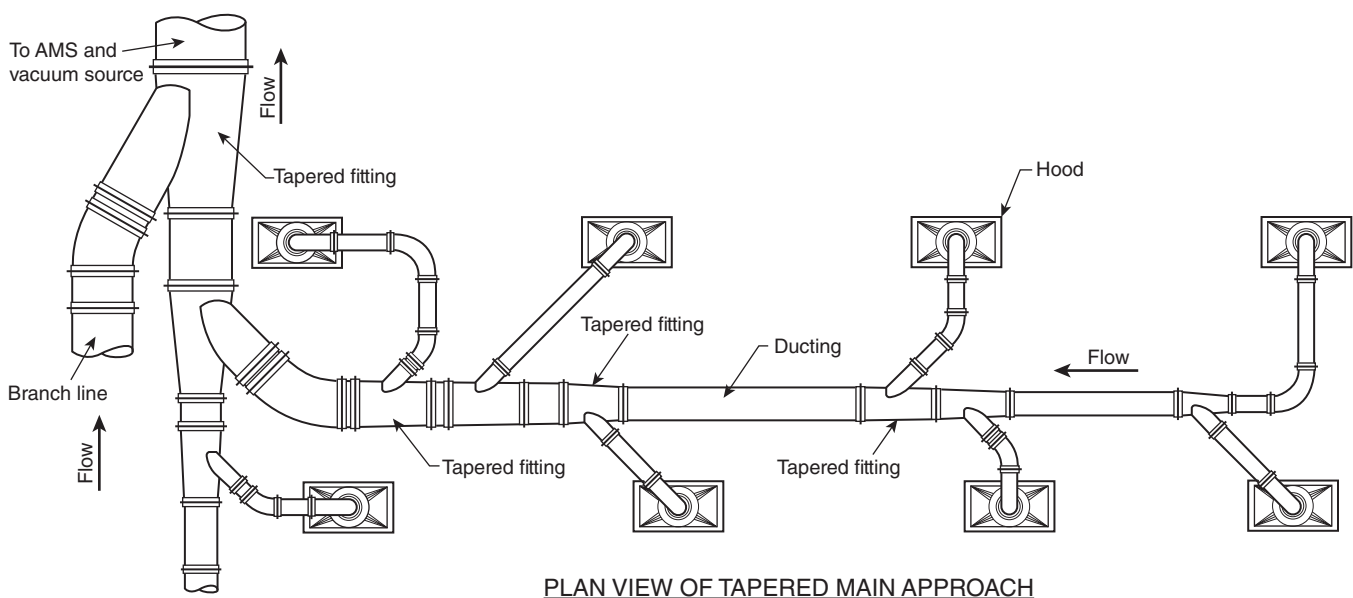
N A.11.2.3.6.4 Proper system design requires that airflows in the various branch lines be balanced to assure minimum air volume flow at each dust source collection point (i.e., hood). When a branch line is disconnected, blanked off, or otherwise modified (e.g., manual slide or blast gate), the modification changes the airflows in all the other branches of the system.

This can lead to an imbalance of airflows that result in flows below the minimum required to keep the dust from accumulating in the ducts.

Use of manual slide or “blast” gates is not recommended. Use of such devices can lead to uncontrolled modification of the flow volumes for both a single line and a system as a whole. The results often lead to improper balance of the system airflows and material accumulations in the ducts. Proper design methods (e.g., balanced-by-design) inherently assure minimum airflows and duct velocities without the use of manual slide or blast gates.

N A.11.2.3.6.5 Installation of branch lines for additional dust sources to an existing dust collection system without compensating for that change will result in lower air volumes and duct velocities for the existing portions of the system. Failing to provide for additional system performance can result in a system performing below the minimum required for keeping the ducts free from material accumulations.

N A.11.2.3.6.6 There are two general methods of combining dust sources (i.e., hoods): the tapered main approach and the plenum approach. The tapered main approach or plenum method gradually gets larger as additional airflows (i.e., dust sources) are merged, which assures duct velocities are kept nearly constant. A plenum method of combining dust sources does not maintain velocities at all locations because a general, much larger duct is used as a plenum or connection point for a series of smaller ducts from the dust sources. This results in portions of the plenum where low duct velocities occur that allow accumulation of materials. These low duct velocities upstream of the subduct entrance occur whether the entrance is angled or perpendicular to the plenum. The plenum method is not recommended for dust collection system design for combustible solids. See Figure A.11.2.3.6.6(a) and Figure A.11.2.3.6.6(b) for illustrations of both methods.



N FIGURE A.11.2.3.6.6(a) Tapered Main Approach.

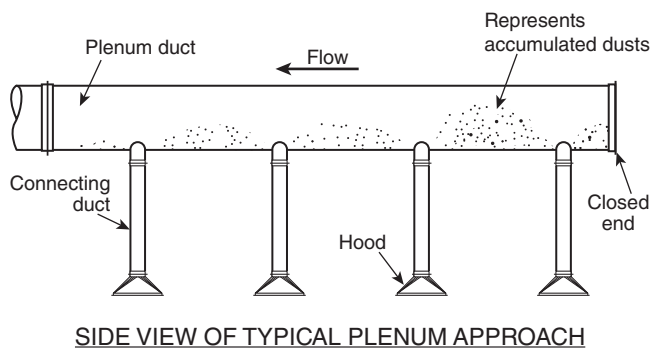


FIGURE A.11.2.3.6.6(b) Plenum Approach.

A.11.2.3.6.7 Examples of spark-producing dust sources would include, but not be limited to, metal grinding, polishing, and cutting/sawing. The purpose of this section is to require segregation/isolation of equipment-generated dust sources, where such ignition sources are produced, from those that are not. This also includes the requirement to isolate such ignition sources from other recognized ignition sources.

A dry-type AMS should not be used with ignition-producing dust sources because its operation inherently produces an environment where high risks of explosion are created. A wet-type AMS provides for quenching of such ignition sources and reduces the risk of explosion.

Where proper isolation of ignition sources is not feasible, a separate independent dust collection system with a wet-type AMS for each individual ignition source would be the recommended solution.

A.11.2.3.6.8 A dry-type AMS often cannot be used with combustible metal dusts. This is due mainly to the inherent operation of such a device and the tendency of combustible material to accumulate inside the unit. A wet-type AMS unit uses a liquid to “capture” and separate the dust from the air or gas stream. This “quenching” of the dust particles (i.e., wetting) inherently reduces risks as long as the device operates properly. Proper selection of the AMS for a dust collection system with combustible metal dusts is critical to the safe operation of the system.

A.11.2.3.6.9 The majority of dust collection systems use centrifugal-type fan packages for inducing the air/gas flow through the system. However, certain types of systems, such as high-velocity, low-volume (HVLV) and venturi-type scrubber systems, might require higher differential pressures that require other types of fans or pressure blowers. Various models are available that will provide the performance characteristics required. Care must be taken to consider the worst-case design situation, such as when the dry-type dust collector filters are nearly blinded or the scrubber requires its maximum differential pressure. Drive motor sizing should also consider when the system is operating with minimal pressure requirements across the AMS, such as when the filters are new and at low resistance to flow.

A.11.2.3.6.10 The optimal location of the fan package (or pressure blower used to create the vacuum) is on the clean side of the dry or wet AMS. This is valid whether the material/dust is combustible or not. This is also optimum for safety considerations because the fan package can be a significant ignition

source and deflagration risk (e.g., due to bearing failure, drive failure, impeller imbalance, friction, wear) when located in the dirty air/gas stream.

A.11.2.3.6.11 The importance of locating the control and monitoring equipment where personnel operating the system are safe can be illustrated by the following conditions:

- (1) Where there is no explosion protection for the dust collector, the personnel operating the controls and monitoring equipment would potentially be at risk.
- (2) Where the AMS is provided with deflagration venting, NFPA 68 describes the danger zone resulting from the actuation of the vent.

To address the listed situations, it is possible to provide blast protection for personnel who must be in the danger zone.

A.11.2.3.6.12 Typical margins of safety used for pneumatic dust handling are 25 percent to 50 percent of the MEC. MEC data for some metals with varying particle size distributions can be found in U.S. Bureau of Mines publication RI 6516, “Explosibility of Metal Powders.” Although the combustible metal powder-air suspension can be held below 25 percent to 50 percent of the MEC in the conveying system, the suspension will, of necessity, pass through the explosible range in the AMS unless the dust is collected in liquid, such as in a wet-type AMS.

A.11.2.3.7 For example, a warning label for steel should state the following:

**DANGER — THIS DUST COLLECTION SYSTEM IS FOR
COLLECTION OF STEEL ONLY. COLLECTING ANY
OTHER MATERIAL CAN CREATE ADDITIONAL FIRE OR
EXPLOSION HAZARDS.**

A.11.2.4.1 Due to ambient temperatures, air/gas temperatures in the area, or other reasons, it is possible that condensation could occur in either the ducting, the AMS, or both. This would create conditions where accumulations can occur (and dry out later, creating an unknown hazard), even with proper duct velocities, or can create unwanted chemical reactions with some of the combustible metal dusts. Insulation, use of heated air/gas, and other methods can be used to mitigate this situation.

A.11.2.4.2 For more information on static (i.e., electrostatic) electricity, see NFPA 77.

A.11.2.4.2.2.3 It is critical that the continuity of the grounding and bonding of the entire dust collection system be checked, verified, and documented on a periodic basis. This check should be done at least annually, but might require additional periodic checks due to operating conditions, changes, and so on.

A.11.2.4.3.2 Short, straight ducts minimize the likelihood of accumulations, reduce the energy requirements to maintain duct velocity, and help to mitigate deflagration hazards. Minimizing the turns reduces both the energy requirements and the likelihood of material accumulations.

A.11.2.4.3.3 Any moisture entering the system can react with most metal powders, generating heat and hydrogen. Hydrogen is extremely flammable and very easy to ignite. It should not be trapped in nonventilated areas of buildings, equipment, or enclosures.

A.11.2.4.3.4 Hoses and flex connections are often required for hood movement, venting of weigh hoppers, and physical

limitations that make the use of metal ducting infeasible. However, the length of hoses or flex connections used should be the minimum required to achieve the desired results. Excessive lengths can result in additional turns, kinks, and other high-energy losses that lead to lower duct velocities, poor hood performance, and accumulations of combustible dusts.

N A.11.2.4.3.5 The typical materials used in hose and flex connection construction tend to create electrostatic charges when air (with or without dust) passes through them. Unless these electrostatic charges are successfully bonded/grounded, the accumulated static charge can be released, resulting in a possible deflagration. Continuity of the bonding/grounding must be achieved by the construction of the hose/flex connection, the use of wire across the span where the hose/flex connection is used, or both. Most static dissipative or conductive hoses have grounding wires that can be used at each end. Use of conductive coatings is not recommended because they can wear off easily due to the abrasion of the dust conveyed.

Hoses normally require significantly more energy to allow air (and dust) flow compared to metal ducting. Typically, poor hose selection can result in 5 to 10 times the energy loss (per foot) compared to an equal diameter metal duct. The type of hose used, especially the interior construction, will greatly influence the energy required. Hoses with smooth interiors (versus convoluted) should be used.

N A.11.2.4.4 A dry-type air-material separator (AMS), as the name implies, does not use any liquids to separate the dust from the airflow. This device includes, but is not limited to, cyclones (i.e., centrifugal collectors), bag or cartridge filter dust collectors, electrostatic collectors, and final or HEPA filters.

Cyclones separate the entrained dust from the air or gas flow by centrifugal, inertial, and gravitational forces. The effectiveness of a cyclone is based on the dust characteristics, physical configuration of the cyclone, inlet velocity and velocity through the cyclone, and dust loading (i.e., weight of dust per mass flow of air or gas, usually in grains per cubic foot). Cyclone efficiency can range from the collection of only large particles to 10 microns and less. However, no cyclone is 100 percent efficient, and even the ultra-high-efficiency designs will have some percentage of dusts below 10 micron passing through. Cyclones can be used to remove heavy dust loadings of large particles prior to a secondary AMS (dry or wet) where this proves beneficial. However, this combination requires more energy and more costs, and might be unnecessary. The main advantage of using a cyclone in place of a filter-type or wet-type AMS is the reduced maintenance, the reduced hazardous conditions associated with filter-type dust collectors, or both. If combustible dusts are involved, the cyclone will likely require deflagration protection and isolation.

Filter bag dust collectors are the most common dry-type AMS units, although cartridge filter AMS units are also used for many dust collection applications. Other than the type of filter media used, the main difference between the devices is the method of providing automatic filter cleaning. By far the most common and proven method is called pulse-jet or reverse-pulse-jet, where compressed air is blown at timed intervals back through the filter media (reverse to the system airflow) to clean the filters. Other methods include reverse-air [which uses a fan or positive displacement (PD) blower to provide reverse airflow to a rotating arm above the filters] and shaker (motor and cam shake the filters when isolated from the airflow) methods. The

pulse-jet method has the advantages of no moving parts in the air stream, less complexity, and typically reduced ignition-source risk.

Electrostatic AMS devices use electrical charges to attract dust particles to plates. This approach is not recommended for metal dusts, and it is not allowed for combustible metal dusts.

Final or high-efficiency particulate arrestor (HEPA) filters are normally used as secondary AMS units after a primary dry-type AMS when the air/gas flow is to be returned (e.g., to the building). These cartridge filter media devices are highly efficient at collecting particles below 10 microns but are limited in their use since they can tolerate only very light dust loadings. They should not be used where pyrophoric combustible metal dusts are involved, as accumulations could lead to hazards (e.g., ignition). These dry-type filters have only limited use with metal dusts.

The hazards of each dry-type AMS should be recognized, and protection against the hazards should be provided. Metal industry experience has demonstrated that the risk of an eventual explosion is high where a bag or cartridge AMS is used to collect combustible metal fines. When these dry-type AMS units are used, they should be located a safe distance from buildings and personnel.

See Figure A.11.2.4.4(a) through Figure A.11.2.4.4(d) for examples of dry-type AMS.

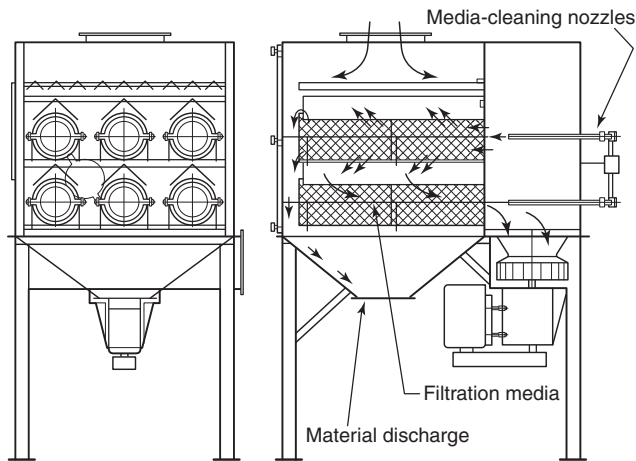
N A.11.2.4.4.1 Historical data show that the application of effective explosion suppression, explosion isolation, and explosion venting is difficult for many combustible metal dusts with a K_{St} greater than 150 bar-m/s. More recent data show that advances in equipment design have demonstrated the ability to protect dusts greater than 150 bar-m/s. However, the ability to effectively protect high K_{St} dusts is largely dependent on the properties of the dust, process in which the dust is being handled, and size of the equipment (e.g., collector, duct). For this reason, it is important to base the protection's ability on the actual dust and process under review.

N A.11.2.4.4.3 Condensing moisture might cause material to stick to interior surfaces and can exothermically react with most combustible metals generating hydrogen.

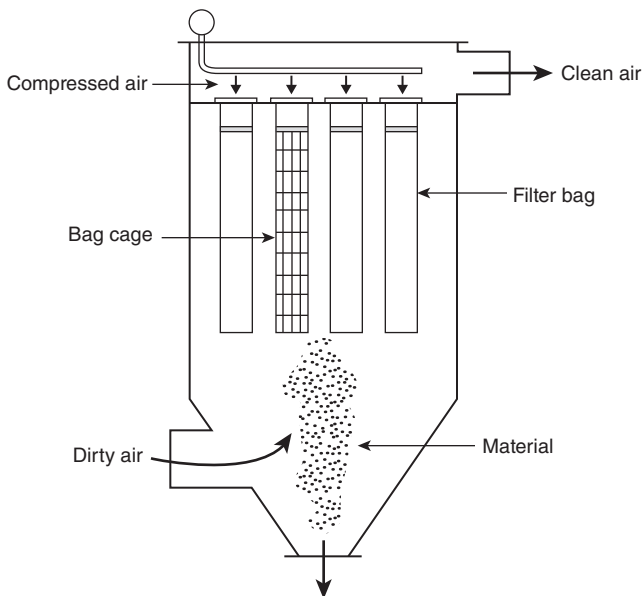
N A.11.2.4.4.4.1 Electrostatic collectors inherently introduce a potential ignition source based on their method of operation.

N A.11.2.4.4.4.3 The concern is that collected dust and filter media are close to the operator; hot embers from operations like grinding could ignite the collected dust and filter media and expose the operator to a flash fire. Wet dust collectors or external dust collectors located a safe distance away from the downdraft table should be used. A DHA could identify circumstances where it would be acceptable to use a self-contained downdraft table with additional protection methods.

N A.11.2.4.4.5 A coating of fine dusts will always occur inside the AMS and on any filter media (if used). The purpose of the requirement is to not allow accumulations of combustible dusts inside the AMS other than the normal operating conditions. An AMS should not be used as a storage hopper. Rectangular dry-type media AMS will tend to accumulate significant dust accumulations on ledges and other surfaces. This is to be avoided where feasible by the use of cylindrical units or designs where this accumulation is limited.



N FIGURE A.11.2.4.4(a) Typical Downflow Cartridge Dry-Type AMS.

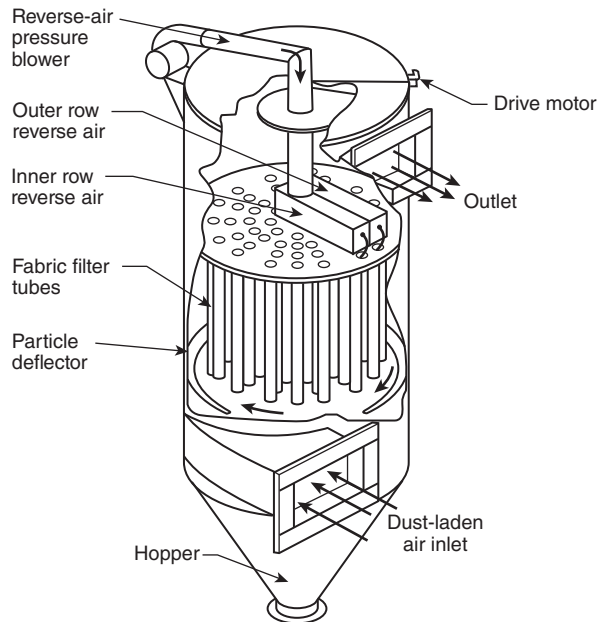


N FIGURE A.11.2.4.4(b) Typical Pulse-Jet Dry AMS/Dust Collector.

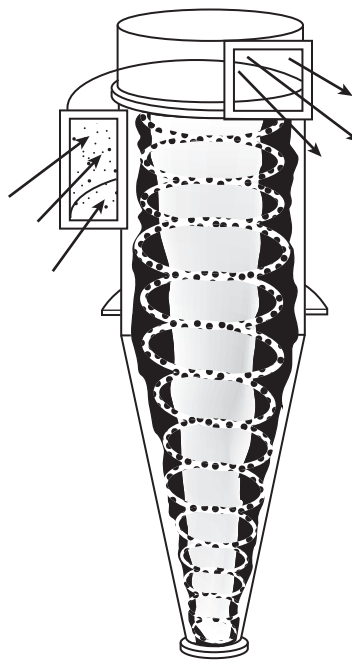
N A.11.2.4.4.9 The following is an example of the required equipment for and the steps of a procedure for replacing filter media:

The required equipment is as follows:

- (1) Nonsparking, conductive tools
- (2) Personal grounding equipment (wrist-strap, flexible cord)
- (3) Bonding cables and clamps
- (4) Personal protective equipment
 - (a) Flame-retardant coveralls
 - (b) Face shield
 - (c) Hard hat
 - (d) Safety glasses
 - (e) Static-dissipative safety boots
 - (f) Nuisance dust mask



N FIGURE A.11.2.4.4(c) Typical Reverse-Air Dry AMS/Dust Collector.



N FIGURE A.11.2.4.4(d) Typical Cyclonic AMS.

The steps of the procedure are as follows:

- (1) Notify system operators that the affected dust collection systems will be shut down and locked out in accordance with the company lockout/tagout procedure.
- (2) Shut down all processes providing powder to the collector (e.g., atomization, classification).
- (3) Isolate the collector by means of valves or blank-off plates in ductwork.

- (4) Disable and lock out pulsing system associated with the collector.
- (5) If a forklift and cage is required for access to the collector, ensure that the forklift and cage are bonded to the collector frame by bonding cables and clamps.
- (6) Ensure that all personnel engaged in the change procedure are bonded to the collector by personal wrist straps and bonding cables at all times during the procedure.
- (7) Open the collector access door/port using nonsparking tools.
- (8) Remove the cartridges/bags, taking care to minimize the generation of suspended dust.
- (9) Ensure that cartridges/bags that have been removed are handled in accordance with established cleaning and disposal procedures.
- (10) Install the new cartridges/bags.
- (11) Perform and document a continuity check.
- (12) Reinstall the access door/port.
- (13) Thoroughly clean the equipment and surrounding area of any residual powder/dust generated as a result of the procedure in accordance with company housekeeping procedures.
- (14) Open the valves leading to/from the collector, or remove any blank-off plates previously installed.
- (15) Purge the collector, if required, and contact QC for purge sign off.
- (16) Remove all locks/tags previously installed and re-energize the pulse system.
- (17) Notify system operators that the procedure is complete and the affected system is operational.

Collectors should be provided with barriers or other means of protection of personnel.

N A.11.2.4.4.10.1 During normal use of cartridge filters, the V portion of the pleats will pack with material that cannot be dislodged during actions such as filter cleaning. This accumulation will allow pyrophoric metal dusts to ignite, creating a high risk for a deflagration.

N A.11.2.4.4.11.2(1) Explosion venting is important for combustible metal dust due to the high maximum explosion pressures reached and the extremely high rate of pressure rise. Where deflagration venting is used, its design should be based on information contained in NFPA 68. For deflagration relief venting through ducts, consideration should be given to the reduction in deflagration venting efficiency caused by the ducts. Dust collectors, when provided by a manufacturer for other applications, seldom have properly sized venting to handle a combustible metal dust explosion.

Historical data show that the application of relationships in NFPA 68 and NFPA 69 based on K_{St} values for explosion suppression, isolation, and venting might not be suitable for certain combustible metal dusts. Caution must therefore be used when applying relationships provided in NFPA 68 and NFPA 69 to metal dusts, and it is important to base the protection's performance on the actual dust and process under review. The manufacturer of the protection equipment should provide experimental justification that the explosion protection is suitable for the hazard.

N A.11.2.4.4.11.2(1)(b) Most combustible metals will react with water (i.e., the oxygen in water can oxidize the metal and generate hydrogen). In most cases, deflagration vent ducts designed for metal dust deflagration would be inadequate to vent a hydrogen explosion or a hybrid hydrogen and combusti-

ble metal dust explosion. Vent ducts could be pitched downward to allow moisture to drain from the vent duct, or vent duct covers could be used to prevent water from entering the vent duct.

Historical data show that the application of relationships in NFPA 68 and NFPA 69 based on K_{St} values for explosion suppression, isolation, and venting might not be suitable for certain combustible metal dusts. Caution must therefore be used when applying relationships provided in NFPA 68 and NFPA 69 to metal dusts, and it is important to base the protection's performance on the actual dust and process under review. The manufacturer of the protection equipment should provide experimental justification that the explosion protection is suitable for the hazard.

N A.11.2.4.4.11.2(2)(b) The maximum allowable concentration of oxygen is very dependent on the material, its chemical composition, and, in the case of particulate solids, the particle sizes. In addition, it is not advisable with many combustible metals to eliminate oxygen completely from the transport gas. During transport, particles can be abraded and broken, exposing unoxidized metal (virgin metal) to the transport gas. When that metal is finally exposed to oxygen-containing air, the rapid oxidation of the virgin metal could produce sufficient heat to ignite the material. It is therefore preferable to provide for a low concentration of oxygen in the transport gas stream to ensure the oxidation of virgin metal as it is exposed during the course of transport.

Historical data show that the application of relationships in NFPA 68 and NFPA 69 based on K_{St} values for explosion suppression, isolation, and venting might not be suitable for certain combustible metal dusts. Caution must therefore be used when applying relationships provided in NFPA 68 and NFPA 69 to metal dusts, and it is important to base the protection's performance on the actual dust and process under review. The manufacturer of the protection equipment should provide experimental justification that the explosion protection is suitable for the hazard.

N A.11.2.4.4.11.2(4) Historically, effective deflagration suppression systems have not been commercially available for highly reactive combustible metals. With some metals and quantities of suppressant, the heat of the combustion of the metal can cause decomposition of the suppressant and produce higher overpressures than the metal alone. (See *"Flammability Limits of Dusts: Minimum Inerting Concentrations."*)

More recently, deflagration suppression systems have become commercially available for some combustible metal dusts. The user should ensure that the supplier of the deflagration suppression system is fully aware of the characteristics of the combustible metal and that the suppression system has been shown to be effective with the specific material being handled in the system. Some suppression systems have only been shown to be effective for combustible metals with P_{max} below approximately 8 bar and K_{St} below approximately 150 bar-m/s.

N A.11.2.4.4.11.2(5) This method is limited in effectiveness due to the high concentrations of inert material required and the potential for separation during handling.

N A.11.2.4.4.11.2(6) For information on dust retention and flame-arresting devices, see Section 9.7 in NFPA 68. The effectiveness in this section is intended to mean that the device has

been certified to be used with the material. Certain particulates can get stuck in the flame-venting device because of the physical shape of the metal particles. The certification should include the kinds of particles for which the flame-arresting device would not be effective. The manufacturer should demonstrate that the device is effective for the type of metal to be collected.

Historical data show that the application of relationships in NFPA 68 and NFPA 69 based on K_{St} values for explosion suppression, isolation, and venting might not be suitable for certain combustible metal dusts. Caution must therefore be used when applying relationships provided in NFPA 68 and NFPA 69 to metal dusts, and it is important to base the protection's performance on the actual dust and process under review. The manufacturer of the protection equipment should provide experimental justification that the explosion protection is suitable for the hazard.

The justification should address potential pressurization of the surrounding building or enclosure as well as a minimum safe distance for personnel.

- **A.11.2.4.4.11.4(A)** The purpose of this requirement is to protect dust collectors that have combustible metals present in the collector. Many dry-type dust collectors are used for collection of dust from grinding and similar operations in which the collected material is not combustible; in these cases, isolation is not required.

Historical data show that the application of relationships in NFPA 68 and NFPA 69 based on K_{St} values for explosion suppression, isolation, and venting might not be suitable for certain combustible metal dusts. Caution must therefore be used when applying relationships provided in NFPA 68 and NFPA 69 to metal dusts, and it is important to base the protection's performance on the actual dust and process under review. The manufacturer of the protection equipment should provide experimental justification that the explosion protection is suitable for the hazard.

- **A.11.2.4.4.13** Recommended design, maintenance, and operating guidelines for recirculation of industrial exhaust systems, as described in the ACGIH publication, *Industrial Ventilation — A Manual of Recommended Practice for Design*, should be followed.
- **A.11.2.4.4.13.1(1)** Adiabatic flame temperatures for some metals are contained in "Explosion Temperatures and Pressures of Metals and Other Elemental Dust Clouds," (Cashdollar and Zlochower, 2007). Metals with calculated adiabatic flame temperatures below 2300°C (4172°F) include iron, copper, nickel, zinc, and lead.
- **A.11.2.4.4.13.1(4)** The system should be designed, maintained, and operated according to accepted engineering practice, and the AMS efficiency should be sufficient to prevent dust in the recycled air from causing hazardous accumulations of combustible dust in any area of the building. This objective could be evaluated based on design calculations or testing prior to operational acceptance.
- **A.11.2.4.4.13.1(5)** OSHA has established limits on oxygen concentration in the workplace. Permissible limits range from no lower than 19.5 percent by volume to no higher than 23.5 percent by volume in air. See 29 CFR 1910.146, "Permit-Required Confined Spaces."

- **A.11.2.4.4.15** Indoor dry-type dust collectors for combustible metal dust should be used only where it is not feasible to use an indoor wet-type AMS or outdoor dry-type AMS. In most cases, an indoor dry-type AMS will create a greater hazard than other options. For instance, a fire in an indoor dry-type AMS can more readily spread to the building. A combustible metal fire in an indoor dry-type AMS can be extremely difficult, if not impossible, for emergency responders to control using normal fire-fighting techniques. Because of this increased hazard, indoor dry-type AMS are allowed only for combustible metals that meet certain thresholds for K_{St} , P_{max} , and minimum ignition energy, and the AMS requires a greater level of protection.

- **A.11.2.4.4.15.3(E)** A break or leak in a filter can allow dust to pass through the fan, which would create a hazard. This often occurs with improper filter installation (whether bag or cartridge).

- **A.11.2.4.4.15.4** This assumes the discharge will be outside and not inside (which involves extensive restrictions discussed in this chapter). Discharging outside to a safe location (and as per regulatory requirements) is always preferred as filters can fail and allow discharge of hazardous dust.

- **A.11.2.4.4.15.5** Accumulation of dust can occur in both the upstream and downstream ducts of collectors. Dust accumulations in the duct can allow an explosion to propagate through significant lengths of duct and rupture the duct.

- **A.11.2.4.4.15.6(2)** Historically, effective chemical isolation systems have not been commercially available for highly reactive combustible metals. More recently, chemical isolation systems have become commercially available for some combustible metal dusts. The user should ensure that the supplier of the chemical isolation system is fully aware of the characteristics of the combustible metal and that the isolation system has been shown to be effective with the specific material to be handled in the system.

The intent is to prevent a deflagration from propagating into the building by rupturing an exhaust duct located inside of the building.

- **A.11.2.4.4.15.7** It is recommended that indoor dry-type AMS for all combustible metals meet these requirements.
- **A.11.2.4.4.15.7(2)** Most combustible metals cannot be effectively extinguished with water because of the potential for steam explosions and the reaction with the metal (which generates hydrogen). Table A.8.3.3 should be consulted to determine if water is an effective extinguishing agent.

For metals not listed in Table A.8.3.3, testing should be performed with representative forms and quantities of the combustible metal to demonstrate that they can be effectively extinguished with water. This testing should be reviewed with the authority having jurisdiction and with the fire fighters responsible for fighting fires at the facility.

- **A.11.2.4.4.15.7(A)** An abnormally high pressure drop can indicate a significant buildup of material or blinding of the filters, which can create a hazard and decrease the flow rate and efficiency of the collection system. This is also a requirement for all dry-type filter media AMS.

- **A.11.2.4.4.15.7(C)(3)** Some fire-extinguishing agents can cause an oxygen deficient atmosphere.

- **A.11.2.4.4.16** See Figure A.11.2.4.4.16.

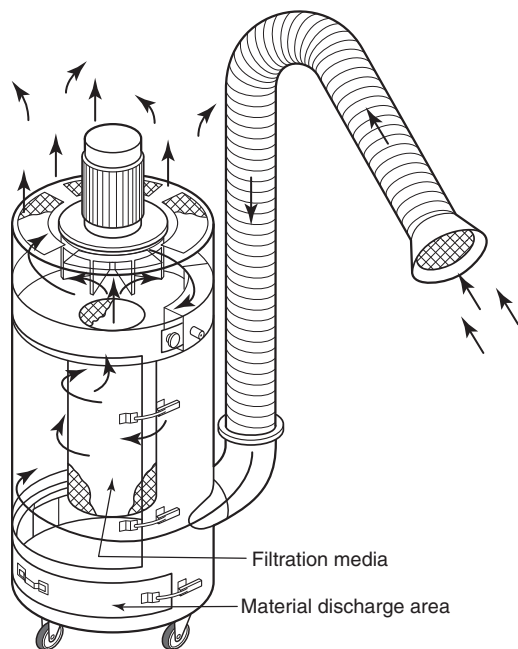


FIGURE A.11.2.4.4.16 An Example of a Portable Media-Type Dust Collector.

A.11.2.4.4.16.4(A) The concern is that if a deflagration did occur in the portable dust collector, flames propagating from the collector could disperse and ignite fugitive dust accumulations in the area, causing a flash fire or explosion. The intent of portable dust collection is to prevent the accumulation of hazardous quantities of fugitive dust. Hazardous levels of dust should be cleaned prior to using the portable dust collector. Portable dust collectors that are rated for Class II areas are typically certified to not serve as ignition sources for existing hazards. However, the collection chamber in a dry collector can still be subject to a deflagration due to other ignition sources, including, but not limited to, hot embers, open flames, and sparks. A deflagration inside the dry collector can propagate outside of the collector or rupture the collector and ignite fugitive dust in the area.

A.11.2.4.4.16.11 It is recommended that each use without a new connection to ground is considered a single use.

A.11.2.4.4.16.13 The purpose is to limit the maximum amount of collected dusts to 2.2 kg (5 lb) at any time. It is good practice to empty this device daily, even if the 2.2 kg (5 lb) limit is not reached.

A.11.2.4.4.17.1 It might be necessary to isolate certain spark- or hot metal particle-producing operations to prevent them from becoming an ignition source for other operations.

Use of dry-type media AMS with any ember- or spark-producing equipment always requires mitigation of the situation. Otherwise, there is high risk of a deflagration event in the AMS.

A.11.2.4.4.17.2 Hot metallic nanoparticles can be present in welding fumes and dusts produced in additive manufacturing processes. When these processes involve reactive metals, the nanoparticulate dust can be pyrophoric.

A.11.2.4.4.17.3 Fires have been caused by the ignition of ordinary combustibles that entered these types of dust collection systems. In some cases, burning paper, labels, rags, cigarettes, and other materials are able to propagate further through a dust collection system.

A.11.2.4.5 Figure A.11.2.4.5(a), Figure A.11.2.4.5(b), Figure A.11.2.4.5(c), and Figure A.11.2.4.5(d) show examples of liquid precipitation collectors.

A.11.2.4.5.5 No wet-type AMS is 100 percent efficient. Over time, the humid air wets the fine particles that pass through the AMS into the outlet and outlet ducting so that the particles agglomerate and tend to build up a combustible cake- or spongelike deposit (sludge) on the inner surface. If left uncleaned, this material can represent a significant deflagration risk.

A.11.2.4.5.6 The vendor providing the wet-type AMS should provide a warranty of performance based on the design conditions. The owner/operator should provide adequate maintenance and monitoring to ensure the AMS meets or exceeds those performance or "efficiency-of-dust-capture" requirements

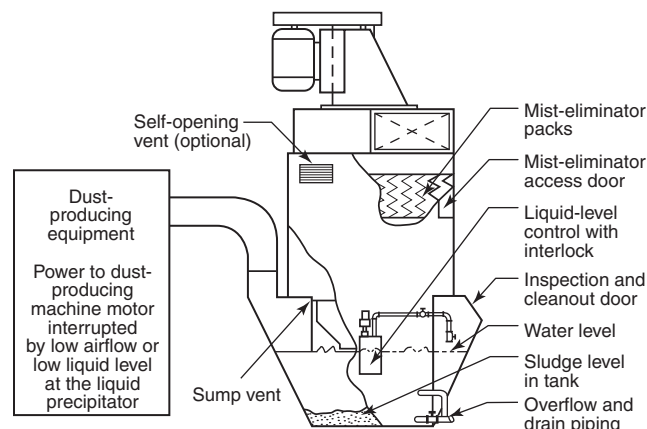


FIGURE A.11.2.4.5(a) Typical Liquid Precipitation Collector for Fixed Dust-Producing Equipment.

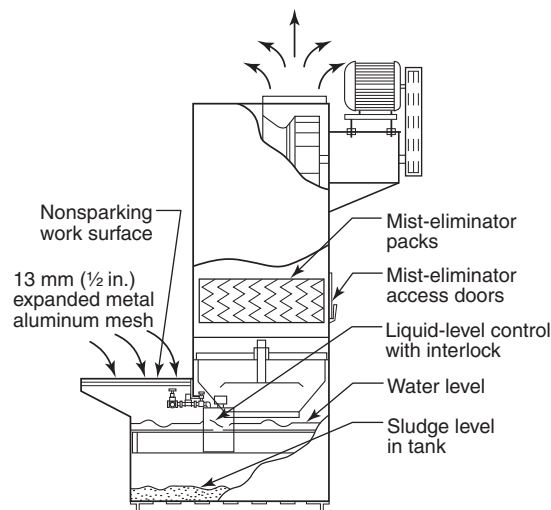
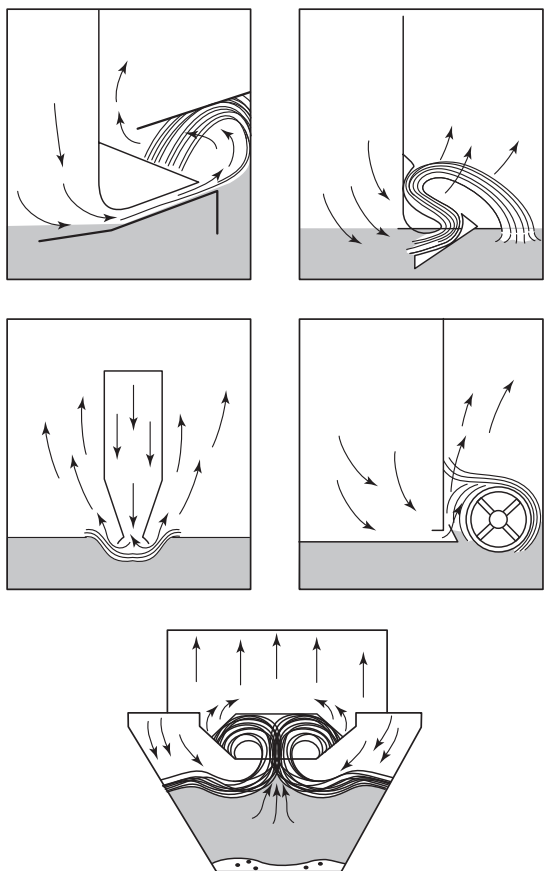


FIGURE A.11.2.4.5(b) Typical Liquid Precipitation Collector for Portable Dust-Producing Equipment.



N FIGURE A.11.2.4.5(c) Five Methods of Precipitating Dust in Precipitators.

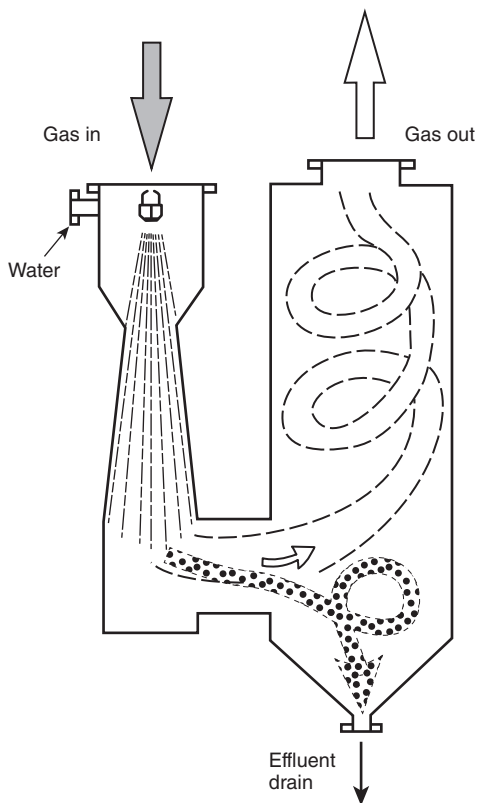
at all times during normal operation. Typically this involves maintaining the operational condition of the AMS and AMD (i.e., usually a fan package) and monitoring the performance of both.

N A.11.2.4.5.8.1 Water level, water supply, or both in the operation of wet-type dust collectors is very important to the overall efficiency of the equipment. AMD (i.e., fan) performance is directly related to the amperage draw of the fan drive motor and can be used in conjunction with the water level or flow rate for system performance monitoring. Therefore, water level or flow rate control logic that shuts the machine down in an underfill, overflow, or lack of flow situation is necessary. Should a malfunction or unacceptable level of performance be detected, this would allow the control logic/system to shut down the vented equipment, the entire system, or both with necessary alarms to assure plant personnel are alerted.

N A.11.2.4.5.9 Most wetted combustible metal dust that is not submerged under a cover of water is highly flammable and very dangerous. The reaction of most combustible metals with water produces hydrogen, which is highly flammable.

N A.11.2.4.5.9.1 Containers preferably should not hold more than 23 kg (50 lb) each.

N A.11.2.4.5.10 The reaction of most combustible metals with water produces hydrogen, which is highly flammable. Most wetted combustible metal dust that is not submerged under a



N FIGURE A.11.2.4.5(d) Typical Venturi-Style Wet-Type AMS/Scrubber.

cover of water is highly flammable and very dangerous. It should not be trapped in nonventilated areas of buildings, equipment, or enclosures. Exhaust vents should be located in areas free of potential ignition sources because of the possible production of hydrogen.

The vent should exhaust to a well-ventilated area where hydrogen gas can dissipate. The vent should not exhaust near inlets to air-handling systems or other equipment that would direct hydrogen gas into a building or other enclosure. See Table 10.3.2.1 of NFPA 55 for guidance on vent discharge location.

It should also be noted that hydrogen is lighter than air. Interactions between differing metal fines, such as magnesium and aluminum alloy (if the aluminum contains more than 0.5 percent to 1 percent copper) in wet collector sludge, can lead to hydrogen evolution and heat generation greatly exceeding that produced by magnesium fines alone. [See Figure A.11.2.4.5(a), Figure A.11.2.4.5(b), Figure A.11.2.4.5(c), and Figure A.11.2.4.5(d).]

N A.11.3 A centralized vacuum cleaning system consists of multiple hose connection stations interconnected by a tubing or piping network to an AMS (dry or wet) and then to a vacuum producer (typically a centrifugal exhaustor or PD blower). A cyclone AMS can be added but is not needed in most cases because the main AMS, such as a filter receiver or wet-type receiver, is usually designed to accept the full rate of material/dust from the vacuum cleaning operations. A single operator

up to many simultaneous operators can use the system depending on the design parameters.

Air is the only gas that is used for pneumatic conveying/transfer as there is no practical way to use inert gases. This, and the fact that the system will vacuum anything that will fit in the hose, makes this type of system a high deflagration risk. This system, whether existing or new, should always be part of the DHA.

Permanently installed vacuum cleaning systems are preferred to portable vacuum systems because they provide a controlled method for removing the combustible metal dust accumulations and for transferring them to a location where the hazards can be controlled or mitigated.

See Figure A.11.3 for typical components of a centralized vacuum cleaning system.

N A.11.3.1.1 The system information and documentation should include the following:

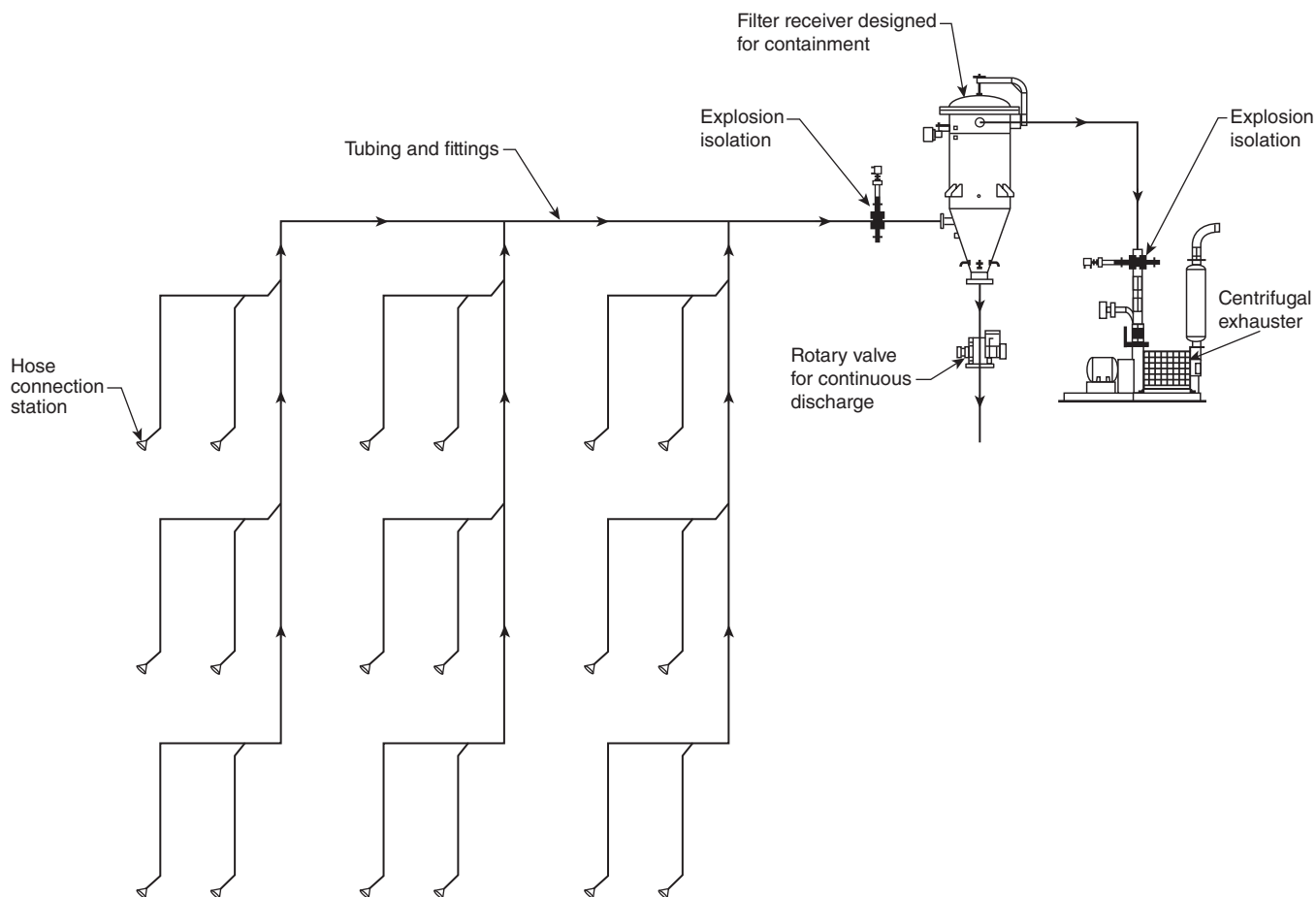
- (1) System design specifications
- (2) System installation specifications
- (3) Equipment specifications
- (4) Operational description
- (5) System deflagration protection and specifications, including explosibility information
- (6) System mechanical and electrical drawings

(7) System controls and specifications

N A.11.3.1.2 Centralized vacuum cleaning systems are designed for specific vacuum cleaning requirements. Changing any of those requirements can significantly change the ability of the system to provide the original design performance. An analysis of any proposed changes should be done to assure the system will still be able to perform as required to meet safety and operational requirements.

N A.11.3.1.3 The minimum required velocity will depend on the operational design parameters. Such parameters include, but are not limited to, the hose length and diameter, type of vacuum tools used, number of simultaneous operators (from a single to many), and conveying distances. A worst-case approach should be used to ensure that the system operates properly at all times (e.g., considering the velocity in the piping/tubing with a single operator cleaning up a major spill).

N A.11.3.2 A centralized vacuum cleaning system represents a significant deflagration risk due to the fact that it is designed to both collect and convey combustible dusts, and that tramp metals or other foreign materials, which could create an ignition source, can enter the system through the vacuum cleaning process. However, through proper design and protection of the system against deflagration, this system can provide for the removal of combustible dusts from the plant areas where dust



N FIGURE A.11.3 Typical Components of a Centralized Vacuum Cleaning System.

accumulations represent a risk to personnel and property. In addition, the dust removed through the vacuum cleaning process will now be located in an area where it can be properly handled with minimal risk.

- N A.11.3.2.1** It is recommended that no more than two simultaneous operators (i.e., hose connection or vacuuming stations) be allowed on any one line to the AMS (e.g., filter receiver if dry or wet receiver). This is to assure that adequate conveying velocity can be maintained with just a single operator on the same line. This is necessary to avoid the situation when a single operator is on a system where large diameter piping is used to allow for multiple simultaneous operators (i.e., three or more), which would result in conveying velocities below what is necessary to keep the conveyed material airborne and moving.

Multiple lines to the AMS can be used to allow for more than two simultaneous operators on the whole system (with no more than two simultaneous operators allowed on each line).

The minimum conveying velocity will vary with the combustible dusts being conveyed. Typically, the minimum conveying velocities should be in the same range as the minimum required for pneumatic conveying of the same material.

- N A.11.3.2.2** It is recommended that 38.1 mm (1.5 in.), 50.8 mm (2.0 in.), or both size inner diameter (ID) hoses be used for housekeeping purposes. It is also recommended that 7.6 m (25 ft) maximum hose length be used. In most systems, the pressure losses (i.e., energy losses) through the hose represent more than 50 percent of the overall system differential pressure requirements. Shorter hose lengths can be used to improve system performance.

Hose of 38.1 mm (1.5 in.) ID are most commonly used for cleaning around equipment and for light-duty requirements, while 50.8 mm (2 in.) ID hoses are used for larger dust accumulations, reduction of air-material concentrations, and for cleaning large open areas.

- N A.11.3.2.3** Since most metal dusts are sensitive to electrostatic discharges, it is critical that proper grounding and bonding be achieved with all vacuum tools used.

- N A.11.3.2.4** The creation of static electrical charges is a high-risk factor with most metal dusts and can be minimized through the use of conductive vacuum cleaning tools and static-dissipative and grounded hose.

- N A.11.3.2.6** For information on static electricity, see NFPA 77.

- N A.11.3.2.7** No PVC or similar tubing or piping should be used because such materials will accumulate electrostatic charges and create unacceptable risks. Commercially available tubing and piping is available specifically for centralized vacuum cleaning systems. Belled male-female connections should be avoided due to the difficulty in assuring proper grounding and bonding (i.e., continuity). Direct grounding/bonding of the connections should include wired connections or other methods verified as effective through testing.

- N A.11.3.2.8** The AMS used in the system is basically a dust collector used at a higher vacuum (i.e., negative pressure). Therefore, it is the intent of this requirement to have the AMS used comply with all the pertinent portions of the dust collection sections where the AMS is discussed.

A dry-type AMS will typically have higher risks than a wet-type AMS when used with vacuum cleaning systems due to the

inherent methods of operation. However, it is necessary to consider all the metal dust characteristics before selecting an AMS for the application.

- N A.11.3.2.9** Dry-type AMS units are not storage hoppers and require the collected material be continuously discharged to a properly designed container.

The device or devices used to provide this continuous discharge must be designed specifically to handle the combustible metal dusts involved and the associated risks.

- N A.11.4** These are self-contained units that typically use a vacuum source created by the combination of compressed air with a venturi (recommended for lower risk) and an AMS that is either dry or wet. Other vacuum producers are possible, but they have inherently higher risk due to electric motors. See also 8.4.2.2 of NFPA 652.

- N A.11.4.3** For example, iron oxide dusts are known to be incompatible with titanium, aluminum, magnesium, and other metal dusts due to the potential for an exothermic thermite reaction. The AMS portion of the assembly should be cleaned unless it has been determined that the materials exhibit no incompatibility.

- N A.11.5.1.3** For more information on static electricity, see NFPA 77.

- N A.11.5.1.4** Any moisture entering the system can react with most metal powders, generating heat and hydrogen. Hydrogen is extremely flammable and very easy to ignite. It should not be trapped in nonventilated areas of buildings, equipment, or enclosures.

- N A.11.5.1.5** Typically, the minimum conveying velocities range from 1078 m/min (3500 ft/min) to 1372 m/min (4500 ft/min) depending on the material being conveyed. For further information, refer to the ACGIH's publication, *Industrial Ventilation — A Manual of Recommended Practice for Design*.

- N A.11.5.1.6** For information on spacing and sizing of ductwork deflagration vents, see NFPA 68. Historical data show that the application of relationships in NFPA 68 and NFPA 69 based on K_{St} values for explosion suppression, isolation, and venting might not be suitable for certain combustible metal dusts. Caution must therefore be used when applying relationships provided in NFPA 68 and NFPA 69 to metal dusts, and it is important to base the protection's performance on the actual dust and process under review. The manufacturer of the protection equipment should provide experimental justification that the explosion protection is suitable for the hazard.

- N A.11.5.1.6.1.3** Historical data show that the application of relationships in NFPA 68 and NFPA 69 based on K_{St} values for explosion suppression, isolation, and venting might not be suitable for certain combustible metal dusts. Caution must therefore be used when applying relationships provided in NFPA 68 and NFPA 69 to metal dusts, and it is important to base the protection's performance on the actual dust and process under review. The manufacturer of the protection equipment should provide experimental justification that the explosion protection is suitable for the hazard.

- N A.11.5.2.1** Metal and metal alloy powders are produced by various processes. These processes, as well as certain finishing and transporting operations, tend to expose a continuously increasing area of new metal surface. Most metals immediately

undergo a surface reaction with available atmospheric oxygen, forming a protective coating of metal oxide that serves as an impervious layer to inhibit further oxidation. This reaction is exothermic.

If a fine or thin, lightweight particle having a large surface area of new metal is suddenly exposed to the atmosphere, sufficient heat will be generated to raise its temperature to the ignition point. Completely inert gas generally cannot be used as an inerting medium, since the metal powder would eventually, at some point in the process, be exposed to the atmosphere, at which time the unreacted surfaces would be oxidized; enough heat would be produced to initiate either a fire or an explosion.

To provide maximum safety, a means for the controlled oxidation of newly exposed surfaces is provided by regulating the oxygen concentration in the inert gas. The mixture serves to control the rate of oxidation while materially reducing the fire and explosion hazard. A completely inert gas can be used if the powder so produced will not be exposed to air in future handling.

N A.11.5.2.3 Oxygen limits of 3 percent to 5 percent have been maintained in aluminum powder systems using a controlled flue gas. Other limits are applicable where other inert gases are used. See U.S. Bureau of Mines publication RI 3722, "Inflammability and Explosibility of Metal Powders."

N A.11.5.2.4 A completely inert gas can be used if the powder so produced will not be exposed to air in future handling. Metal powder produced without oxygen is more highly reactive than metal powder produced by conventional means.

N A.11.5.2.6 Condensing moisture can cause material to stick to ducts and can exothermically react with most combustible metals generating hydrogen.

N A.11.5.2.7 Condensing moisture might cause material to stick to ducts and can exothermically react with most combustible metals, generating hydrogen.

N A.11.5.2.8 Typically, the minimum conveying velocities range from 1078 m/min (3500 ft/min) to 1372 m/min (4500 ft/min) depending on the material being conveyed. For further information, refer to the ACGIH's publication, *Industrial Ventilation — A Manual of Recommended Practice for Design*.

N A.11.5.3.4 Ultimately, all fans or blowers in dust collection systems accumulate sufficient powder to become a potential explosion hazard.

N A.11.6.1 A high-efficiency, cyclone-type collector presents less of a hazard than a bag- or media-type collector and, except for extremely fine powders, will usually operate with fairly high collection efficiency. Where cyclones are used, the exhaust fan discharges to atmosphere away from other operations. It should be recognized that there will be some instances in which a cyclone collector can be followed by a fabric-, bag-, or media-type collector or by a scrubber-type collector where particulate emissions are kept at a low level.

The hazards of each type of collector should be recognized and protected against. In each instance, the fan will be the last element downstream in the system. Because of the extreme hazard involved with a bag- or media-type collector, consideration should be given to a multiple-series cyclone with a liquid final stage.

Industry experience has clearly demonstrated that an eventual explosion can be expected where a bag- or media-type collector is used to collect combustible metal fines. Seldom, if ever, can the source of ignition be positively identified. In those unusual instances when it becomes necessary to collect very small fines for a specific commercial product, it is customary for the producer to employ a bag- or media-type collector. With the knowledge that strong explosive potential is present, the producer will locate the bag- or media-type collector a safe distance from buildings and personnel.

If a bag- or media-type collector is used, the shaking system or dust-removal system can minimize sparking due to frictional contact or impact. Pneumatic- or pulse-type cleaning is more desirable because no mechanical moving parts are involved in the dusty atmosphere. If the bags are provided with grounding wires, they can be positively grounded through a low-resistance path to ground. Where bags are used, it is customary that the baghouse be protected by an alarm to indicate excessive pressure drop across the bags. An excess air-temperature alarm is also frequently employed.

A bag- or media-type collector is customarily located at least 15 m (50 ft) from any other building or operation. It is not customary to permit personnel to be within 15 m (50 ft) of the collector during operation or when shaking bags. Explosion vents are usually built into the system, as described in NFPA 68. Care should be exercised in locating the vents because of the possibility of blast damage to personnel or adjacent structures.

N A.11.6.1.2 See NFPA 68 for the method to calculate the length of a fireball issuing from a vented collector.

N A.11.6.1.2.2 Historical data have shown that the application of relationships in NFPA 68 and NFPA 69 based on K_{st} values for explosion suppression, isolation, and venting might not be suitable for certain combustible metal dusts. Caution must therefore be used when applying relationships provided in NFPA 68 and NFPA 69 to metal dusts, and it is important to base the protection's performance on the actual dust and process under review. The manufacturer of the protection equipment should provide experimental justification that the explosion protection is suitable for the hazard.

N A.11.6.1.5 For information on precautions for static electricity, see NFPA 77.

N A.11.6.1.7 Explosion venting is especially important for combustible metal dust due to the high maximum explosion pressures reached and the extremely high rate of pressure rise.

For information on the design of explosion vents and predicting the size of the fireball, see NFPA 68. Dust collectors, when provided by a manufacturer for other applications, seldom have properly sized venting to handle a combustible metal dust explosion.

N A.11.6.2.2 The blank is provided for segregation and must be removed before restoring the equipment to operation.

N A.11.6.4 Some collector bags or other types of media or screens have fine, noninsulated wire enmeshed into, woven into, or otherwise fastened to the cloth. These items are always securely grounded. It should be pointed out that grounding is not a positive guarantee of static charge removal because there is no dependable force to cause the charges to move across the nonconducting area of the fabric to the grounded wires. Often, a substantial potential difference can be measured. Also, it is

possible that a wire in the cloth could break in such a way that it is no longer grounded. Such a wire serves as a capacitor and could store a static charge.

N A.12.2 Nanometal powder provisions in Chapter 12 and the rest of this standard are limited to fire, flash fire, and explosion protection considerations. Nanometal powder toxicity considerations, applicable to both combustible and noncombustible nanometals, are outside the scope of this document.

N A.12.2.2 A mixture of 99 percent by weight micron-scale iron powder with 1 percent of 35 nanometer titanium powder has been ignited by electrostatic charge generation in a plastic hose. (See Wu, 2014.)

N A.12.2.4 Any powder or dust collection methods used should be included as part of the DHA.

N A.12.3.1.1 Equipment used and energy generated during exploding wire production of nanometals are described and quantified in the following publications:

- (1) Lerner, M., A. Vorozhtsov, Sh. Guseinov, and P. Storozhenko, "Chapter 4: Metal Nanopowders Production," *Metal Nanopowders: Production, Characterization, and Energetic Application*
- (2) Nazarenko, O., et. al., "Chapter 3: Electroexplosive Nanometals," *Metal Nanopowders: Production, Characterization, and Energetic Application*

N A.12.3.1.2 Guidance for blast wave protection can be found in the Center for Chemical Process Safety's *Guidelines for Consequence Analysis of Chemical Releases* and in the chapter on explosion hazards in NFPA's *Fire Protection Handbook*.

N A.12.3.2.1 Figure A.12.3.2.1 is a process flow block diagram for nanometal production via plasma exposure heating and subsequent recondensation. Plasma temperatures required for commercial nanometal production of most metals are about 6000 K for an immersion period of 0.5 to 1 ms, and about 5000 K for longer exposure periods.

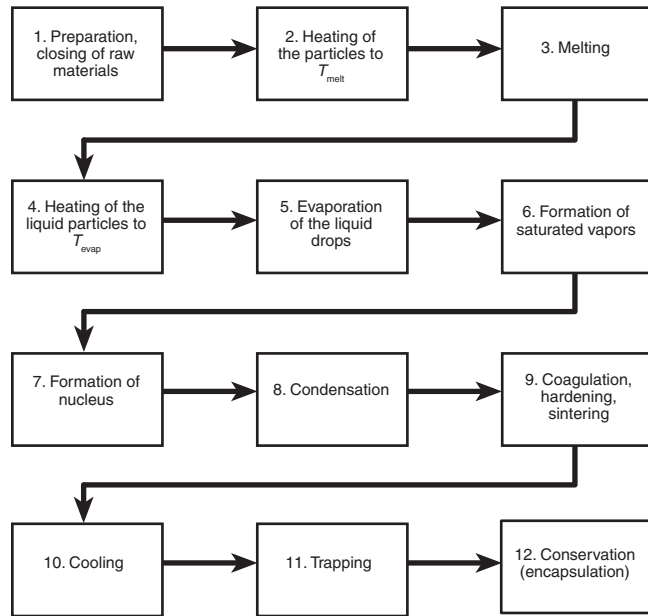
N A.12.3.3.1 Chemical process hazard evaluation methods and associated engineering process design methods are described in *Guidelines for Hazard Evaluation Procedures* and *Guidelines for Engineering Design for Process Safety*.

Reactants with special flammability, reactivity, and stability properties include sodium borohydride and hydrogel matrices containing iron, cobalt, nickel, copper, silver, and ruthenium. (See Sahiner, 2013.)

N A.12.3.3.3 Examples of flammable and combustible liquid reactants and solvents used for nanometal synthesis are dimethylformamide for silver nanoparticles, toluene used in gold nanoparticle production, and ethanol for synthesis of nanoparticles of palladium, platinum, gold, and rhodium. (See Liz-Marzan, 2004.)

N A.12.3.4.1 Biosynthesized metallic nanoparticles have advantages of reduced environmental impact, biochemical stability, and biocompatibility that render them attractive for antimicrobial applications; imaging applications; catalytic applications, such as reduction of environmental contaminants; and electrochemical applications, including sensing. (See Schrofel, 2014.)

Bioprocess safety guidelines are available in *Guidelines for Process Safety in Bioprocess Manufacturing Facilities*.



N FIGURE A.12.3.2.1 Essential Stages of Plasma-Chemical Process to Produce Disperse NP by Recondensation.

N A.12.3.5 Metallic nanostructured coatings of various materials, including, but not limited to, paperboard, aluminum foil, and other metals, can now be produced by thermal spray pyrolysis processes. One example of this is described in the paper by Mäkelä, et al., "Nanoparticle Deposition from Liquid Flame Spray onto Moving Roll-to-Roll Paperboard Material."

N A.12.4.1 Nanograde aluminum and titanium have been shown to auto-ignite during conveying in ducts with elbows. (See Wu, 2010.) LOC values for these and other nanometals can be lower than the LOC values currently in Table A.1.1.3(b) and in NFPA 69, which are based on micrometer-sized dust samples. (See Mittal, 2013.)

N A.12.4.4 Although explosibility tests with several nanometals have resulted in P_{\max} values similar to those obtained with samples of larger particulate of the same material (see Krietsch, 2015), tests with other nanomaterials such as magnesium have produced the highest P_{\max} values with nanometals of about 400 nanometer diameter (see Mittal, 2014). Some of the testing with successful measurements of P_{\max} for nanomaterials required special sample injection methods to avoid preignition during sample transport into the test chamber.

N A.12.5.1 For example, the physical size of nanoparticles present unique problems for typical AMS devices. Where significant quantities of nanoparticles are present, the device used to separate these particles from the conveying air or gas should provide separation efficiencies which meet the hazard mitigation requirements.

N A.13.2.1 A DHA for additive manufacturing and auxiliary equipment using combustible metal powders requires a comprehensive understanding of this complex equipment. Manufacturer's literature addressing the hazards of using this equipment is necessary but not sufficient input for the DHA. Inerting decisions should be based on the combustibility properties of the particular alloys being used.

- N A.13.2.3** The 22.7 kg (50 lb) threshold was established by the technical committee as a subjective limit, based on the higher hazard posed by handling large quantities of material.
- N A.13.2.4** See NFPA 79 for further information on emergency shutdown.
- N A.13.2.4.3** The local manual shutdown should be near the control station for the machine. The remote manual shutdown should be located a minimum of 7.6 m (25 ft) away from the machine and in the path of the means of egress for the area.
- N A.13.2.5.1** See NFPA 77 for information on conductive and static-dissipative liners and containers. If powder is received in containers that are not metallic or static dissipative, extreme care should be used in the transfer of metal powder from the container. The amount of free fall of the powder should be minimized. The rate of transfer should be slow to reduce the amount of static charges produced by the transfer. Although the shipping container cannot be grounded/bonded, consideration should be given to embedding a metallic grounding stick into the shipping container that would be in contact with the metal powder.
- N A.13.2.5.2** The committee intends that containers used for shipping and handling of additive manufacturing alloys will be required to be conductive or static dissipative in the next edition and that this permissive provision will be removed.
- N A.13.3.2.2** Bonding methods are described in NFPA 77.
- N A.13.3.2.4** The committee intends that containers used for intermediate handling of additive manufacturing alloys will be required to be conductive in the next edition and that this permissive provision will be removed.
- N A.13.3.2.5** The formation of dust clouds usually can be controlled by eliminating the free fall of the metal powder during transfer and controlling the flow rate of the transferring operation.
- N A.13.3.3.2** Bonding methods are described in NFPA 77.
- N A.13.3.3.4** The committee intends that containers used for sieving operations of additive manufacturing alloys will be required to be conductive in the next edition and that this permissive provision will be removed.
- N A.13.3.3.5** The formation of dust clouds can usually be controlled by eliminating the free fall of the metal powder during transfer and controlling the flow rate of the transferring operation.
- N A.13.3.3.6** The general precaution is just a visual examination of the material to be sieved. Tramp metal, flashings, and other metal forms that won't pass through the sieve can be removed manually prior to sieving the metal powder.
- N A.13.3.4.2** The formation of dust clouds can usually be controlled by eliminating the free fall of the metal powder during transfer and controlling the flow rate of the transferring operation.
- N A.13.3.5.1.1** Nitrogen can be considered as a purge gas/extinguishing agent for iron, steel, and many alkali metals. Gaseous nitrogen is not a suitable extinguishing agent for titanium, tantalum, zirconium, niobium, hafnium, and magnesium. Some nitrogen–argon blends have been shown to be effective extinguishing agents for some combustible metals.
- N A.13.3.5.1.3** The introduction of noncompatible materials has the potential to result in an uncontrolled exothermic reaction. Only metal alloys known to be compatible with one another should be introduced without a thorough cleaning of the machine.
- N A.13.3.5.4.1** Some printed parts trap loose powder within internal cavities. The part can be gently rotated prior to its removal to allow loose powder to be extracted. The part should be held in a position that minimizes the free-fall distance from the part to the floor of the print chamber.
- N A.13.3.5.5.1** Because of the ability to print almost any configuration, completed parts should be expected to contain loose metal powder within internal cavities. The completed part can be rotated several times within the chamber to allow the loose powder to be extracted.
- N A.13.4.4** Proper use of the cleaning equipment can prevent the free fall of metal powder during cleaning operations, which reduces the potential for dust clouds. When brushes are used for cleaning, gentle rather than forceful strokes should be used to direct the metal powder to the collection device.
- N A.13.5** Equipment pertinent to this section includes auxiliary and cleaning equipment as well as the 3D printer itself. Since operating instructions and manuals for this equipment are often translations from other languages besides English, they should be verified to be understandable in English or the language(s) understandable to the operator. Several equipment manufacturers provide equipment-specific training courses and offer certifications for operators that have been adequately trained for safe operation, maintenance of the equipment, or both.
- N A.13.5.1** A qualified person approach can be considered if this training is not available.
- The operating manuals often contain requirements or guidance that are not required by consensus standards but are important for the proper and safe operation of the equipment.
- N A.13.6.2** Emergency responders will make decisions based on the information provided on the machines. It is important that emergency responders understand the posted signage. Generally, it is better to spell out the powder composition rather than use chemical abbreviations that might not be understood by emergency responders.
- Δ A.14.1** Finely divided dry alkali metals and finely divided alkali metals dispersed in a flammable liquid can exhibit pyrophoric properties. Prior to the handling of these materials, the vendor of the alkali metals, alkali metals alloy, or alkali metals dispersion should be consulted for safe practices. These practices include the design of the facilities for storage and handling of these materials, protective clothing requirements, training requirements, and general safety precautions.
- Dry alkali metals and alkali metal alloy powders are pyrophoric in nature and water reactive. Precautions are required because, on exposure to air, the powders can ignite or explode.
- Dispersions of alkali metals and dispersions of some alkali metals in organic solvents present special concerns. In addition to the water reactivity/pyrophoricity due to reactive metals, solvents present the concerns of flammable or combustible liquids and vapors. The SDS provided by the supplier of the material, NFPA 30, and NFPA 77 are applicable to addressing the problems of combustible liquids and vapors.

A.14.1.2.1 Alkali metals react with moisture from any available source, such as concrete, the atmosphere, and human skin. The degree and speed of the reaction vary with the conditions; therefore, the best approach is to take precautions to keep moisture away from alkali metals.

A.14.1.3.1 Alkali metals in contact with moisture form alkali metal hydroxides and alkali metal oxides, which will cause caustic burns. Alkali metals in contact with human skin will react with body moisture and cause thermal and caustic burns.

A.14.1.3.2 Hazards involved with handling molten alkali metals are significantly greater than those involved with handling solid alkali metals due to enhanced reactivity, heat of reaction, and elevated temperatures.

A.14.1.3.2.2 Fire risk is significantly reduced when the outer clothing layer is kept dry

A.14.1.4.1 Thermite reactions are extremely exothermic, [e.g., temperatures in excess of 2204°C (4000°F)]. A thermite reaction typically occurs between one metal oxide and another metal which reduces that oxide. The main concern is for iron oxide and fine magnesium particulate, especially powder, and molten magnesium, although there are documented instances of magnesium grinding fines initiating such a reaction. The thermite reaction is not necessarily limited to magnesium and iron oxide. There have been recorded incidents where copper oxide and/or lead oxide in contact with magnesium have created the conditions for a thermite reaction. Once initiated via a heat source, a thermite reaction is vigorous and should be treated as a metal fire.

A.14.2 Consideration should be given to automatic fire detection systems in alkali metal production plants to ensure life safety.

A.14.2.1.4 The requirement for watertight roof decks is an effort to ensure that buildings are designed and maintained to minimize possible leaks from weather conditions. Special care should be given to maintaining these roofs, especially in climates where heavy amounts of snow are expected.

A.14.2.1.6 Because of the potential presence of mineral oil on the floor, nonslip surfaces should be provided.

A.14.2.1.7 Floor drains typically are connected to systems that contain water, which when in contact with an alkali metal will result in a violent reaction.

A.14.2.1.9.1 Laboratories, bathrooms, and other areas not dedicated to the processing of alkali metals can have water leaks. Consideration needs to be given to preventing water from such leaks from entering the alkali metals processing areas and creating fire and explosion hazards.

A.14.2.1.10 A ridged or peaked roof that allows for natural ventilation of hydrogen is recommended.

A.14.2.2.2 The plan should include specific actions in the event of an alkali metal fire and should be coordinated with the local facility management, responding fire fighters, and medical personnel.

The plan should pay special attention to the extreme hazards associated with alkali metal–water reactions that might occur with sprinkler water. Specific attention should be paid to an evacuation plan for personnel in the event of any release of water.

The particulate fumes given off by burning alkali metals are very corrosive; therefore, nonessential personnel in the vicinity should be evacuated to a safe distance, with special attention given to shifting winds. Where frequent alkali metals fires can affect local environmental quality conditions, an exhaust treatment system should be provided.

Properly trained personnel who work with alkali metals know its hazards. Such personnel will have the greatest ability to extinguish an alkali metal fire in its incipient stage. Training should include sufficient information to determine whether extinguishment can be accomplished safely and effectively.

An alkali metal at room temperature and in the presence of incompatible materials can reach its melting point and the autoignition temperature.

The degree of reaction and the amount of time to produce the melting point and autoignition temperature vary with surrounding conditions, with the temperature of the exposed alkali metals being the major factor. At low temperatures or temperatures within a few degrees of the melting point of the alkali metal, the reaction is slower and with reduced intensity. At higher temperatures, the reaction is accelerated and more intense.

When fighting an alkali metal fire, it is important that fire fighters be aware of the dangers of burning alkali metal. When molten alkali metal reacts with materials such as water or flammable or combustible liquids or gases, molten alkali metal can be ejected a considerable distance. The severity of alkali metal reactions varies with a multitude of conditions.

An alkali metal in contact with moisture and air forms alkali metal hydroxides and alkali metal oxides, which will cause caustic burns if personnel do not have adequate personal protective equipment.

A.14.3.2.1 Organic materials in the presence of oxides of potassium or NaK can create an explosive, shock-sensitive mixture.

Δ A.14.6.1.1 Dispersions of alkali metals in organic solvents present special concerns. In addition to the water reactivity/pyrophoricity due to the reactive metal, solvents present the concerns of flammable or combustible liquids and vapors. The SDS provided by the supplier of the material, NFPA 30, and NFPA 77 are applicable to addressing the problems of combustible liquids and vapors.

A.14.6.1.2.2 Organic materials in the presence of oxides of potassium or NaK can create an explosive shock-sensitive mixture.

A.14.6.1.2.3 Solid alkali metals are supplied in a variety of forms (e.g., ingots and ribbon), which are often individually protected in small cans or airtight foil pouches. If individual containers are not supplied and the containers are opened, alkali metal is exposed to surrounding air, causing slow reactions to take place. It is for this reason that, once the container is opened, only the amount of alkali metal intended to be used should be removed and the container should be immediately resealed.

A.14.6.1.2.4 If left open for more than 15 minutes, the container should be purged with a gas that is inert to alkali metals.

A.14.6.4.1.4 See A.14.8.1.2.1.3.

A.14.6.4.1.6 In the assessment of the amounts needed for process use, risks and fire exposures should be evaluated with other processing requirements. Alkali metals in containers staged for melting should be considered process vessels.

A.14.7 Section 14.7 applies to operations where alkali or alkali alloys are subjected to processing or finishing operations. The operations specified in Section 14.7 can include, but are not limited to, grinding, buffing, polishing, sawing, and machining of solids. Media blasting operations include, but are not limited to, abrading, etching, applying an anchor pattern, wheel blast, centrifugal wheel blast, sand blast, grit blast, air blast, airless blast, siphon blast, suction blast, abrasive shot blast, peening, and shot peening of solids.

A.14.8.1 A number of small buildings or structures separated from each other, as opposed to a single larger building, reduce the risks associated with handling and processing alkali metals. In the event of an uncontrolled alkali metals emergency, property damage would be comparatively reduced.

A.14.8.1.2.1.1 Alkali metal is shipped from alkali metals manufacturers in UN specification containers that should continue to act as storage containers. Containers should be sealed to remain airtight, with the alkali metal coated with mineral oil or packed under an argon cover. Containers used to store alkali metals under mineral oil for long-term storage (over 3 months) should be inverted to redistribute the mineral oil covering the alkali metal. Containers packed under an argon cover should be checked regularly to verify the integrity of the container seal. When alkali metal is returned to any shipping container, the protective method used by the manufacturer should be duplicated.

A.14.8.1.2.1.3 Alkali metals are known to be incompatible with the following materials:

- (1) Inorganic and organic acids
- (2) Halon 1211
- (3) Halon 2402
- (4) Carbon tetrachloride
- (5) 1,1,1-trichloroethane
- (6) Oxidizers such as nitric acid
- (7) Chromic acid
- (8) Phosphoric acid
- (9) Hypochlorous acid
- (10) Reducing acids such as sulfuric, hydrochloric, and sulfamic acid
- (11) Mineral oil for NaK
- (12) Halogenated hydrocarbons
- (13) Water
- (14) Alcohols
- (15) Carbon dioxide

Oxalic acid, phenol and organic acid mixtures, and compounds such as paint strippers or metal cleaners are also reactive and should not be stored in the vicinity of an alkali metal.

A.14.9 Alkali metal fire residue products can include metallic alkali metals, alkali metal nitrides, alkali metal oxides, or alkali metal hydroxides, which can absorb moisture.

A.14.9.1.1 Once an alkali metal fire is extinguished, alkali metal is usually still present in sufficient quantity to create adverse reactions and exhibit the burning characteristics of alkali metals. Alkali metal fire residues can include other reactive components. These residues can react with each other and

cause re-ignition. Containers of residues can be purged with argon gas, or the residues can be coated with water-free mineral oil to reduce the potential for reaction. Under solid waste environmental regulations, these residues could be considered a hazardous waste and could be subject to hazardous waste packaging, storage, notification, and disposal regulations.

A.14.9.2.2 Alkali metals react with moisture from any available source, such as concrete, the atmosphere, and human skin. The degree and speed of the reaction vary with the conditions; therefore, the best approach is to take precautions to keep moisture away from alkali metals.

A.14.9.3.2.1 The longer the material is stored, the greater the risk of hazardous reactions.

A.14.9.4 Attention is called to the hazardous conditions that could exist both inside and outside the plant if cutting torches are used to dismantle dust collectors or powder-producing machinery before all dust accumulations have been removed.

It is a commonly recognized practice that operators of cutting or welding torches be required to obtain a written permit from the safety or fire protection officer of the plant before using their equipment under any condition around metal powder plants.

• **A.15.1** The overall organization has been to group common operations. Additional hazards or requirements for specific legacy metals are at the end of each section.

• **A.15.1.2** The reaction of water and water reactive metals produces hydrogen. Hydrogen is extremely flammable and very easy to ignite. It should not be trapped in nonventilated areas of buildings, equipment, or enclosures.

• **A.15.1.3** Thermite reactions are extremely exothermic, [e.g., temperatures in excess of 2204°C (4000°F)]. A thermite reaction typically occurs between one metal oxide and another metal that reduces that oxide. The main concern is for iron oxide and fine legacy metals particulate, especially powder, and molten legacy metals, although there are documented instances of legacy metals grinding fines initiating such a reaction. The thermite reaction is not necessarily limited to legacy metals and iron oxide. There have been recorded incidents where copper oxide and/or lead oxide in contact with legacy metals have created the conditions for a thermite reaction. Once initiated via a heat source, a thermite reaction is vigorous and should be treated as a metal fire.

• **A.15.1.4** For practical consideration, a eutectic reaction involving legacy metals is one involving another metal, usually iron or nickel base, where the mixture melts at a lower temperature than either of the individual metals.

• **A.15.1.7.2** An inert gas chamber, commonly known as a dry welding box, or glove box, typically is used for performing legacy metal-welding operations. Such equipment is often equipped with a mechanical vacuum pump system with an inert gas backfilling and purging system to effect evacuation of the chamber and provide a regulated supply of inert gas at or slightly above atmospheric pressure. For further information, consult the equipment manufacturers or the American Glove Box Society.

Cleaning methodologies should consider the hazards of generating airborne dusts and the dangers associated with the use of vacuum cleaners.

N A.15.2 Consideration should be given to automatic fire detection systems in legacy metal production plants to ensure life safety.

N A.15.2.6.1.1 The requirement for watertight roof decks is an effort to ensure that buildings are designed and maintained to minimize possible leaks from weather conditions. Special care should be given to maintaining these roofs, especially in climates where heavy amounts of snow are common.

N A.15.2.7.1.1 Where surfaces on which dust can collect are unavoidably present, they can be covered by a smooth concrete, plaster or noncombustible mastic fillet having a slope sufficient to prevent accumulation. An angle greater than the angle of repose is recommended.

N A.15.2.9.1 For information on deflagration venting, see NFPA 68.

N A.15.2.11 A ridged or peaked roof that allows for natural ventilation of hydrogen is recommended.

N A.15.2.12.1 The need for building deflagration venting is a function of equipment design, particle size, deflagration characteristics of the dust, and housekeeping. As a rule, deflagration venting is recommended unless it can be reasonably ensured that hazardous quantities of combustible and dispersible dusts will not be allowed to accumulate outside of equipment.

Where building explosion venting is needed, locating the operation in an open structure or in a building of damage-limiting construction is the preferred method of protection. Damage-limiting construction involves a room or building designed such that certain interior walls are pressure resistant (i.e., can withstand the pressure of the deflagration) to protect the occupancy on the other side, and some exterior wall areas are pressure relieving to provide deflagration venting. It is preferable to make maximum use of exterior walls as pressure-relieving walls (as well as the roof, wherever practical), rather than to provide the minimum recommended. Further information on this subject can be found in NFPA 68.

Deflagration vent closures should be designed such that, once opened, they remain open to prevent failure from the vacuum following the pressure wave.

N A.15.2.12.3 High-momentum discharges from relief valves within buildings can disturb dust layers, creating combustible clouds of dust. For further information on restraining vent closures, see NFPA 68.

N A.15.2.13.1.1 In some metal processing operations, process equipment requires cooling water. Under these circumstances, a hazard operations review should be conducted on the site and locations to determine where to feed the water. Water pipes necessary for providing cooling water should be located to minimize their exposure to areas where the risk of metal fires is possible. It is recognized that metal powders can be ignited by exposure to hot surfaces. As such, the use of cooling water in a judicious manner is a means by which hot surfaces can be reduced or eliminated.

N A.15.3.2.3 Chips, turnings, powders, or swarf that is being preheated or charged to melting pots will autoignite at temperatures below that of the solid metal. Solids should be free of these smaller particles, which can ignite and, in turn, ignite the solids. There should be no depression directly beneath the

magnesium storage area where water can accumulate or flow during a fire.

N A.15.3.2.3.1.2 Because concrete always contains water, concrete in contact with hot materials such as molten magnesium can result in an extremely violent reaction, including violent spalling of concrete.

N A.15.3.2.3.2 The contact of moisture with molten magnesium metal can result in a violent explosive reaction with the generation of steam or hydrogen. It is important to establish and document a method of preheating that heats all material to a minimum temperature of 121°C (250°F) to ensure the removal of moisture. A higher heating temperature might be necessary if the metal is contaminated with corrosion products, salts, or other foreign materials. Molds or tools that will come into contact with molten magnesium should be similarly preheated.

N A.15.3.2.3.4 Iron scale and molten magnesium can create a thermite reaction. The interior of a crucible furnace, normally known as the “setting,” is a critical area of concern. With the use of sulfur hexafluoride (SF₆) and other protective atmospheres, the problem of iron scale forming above the melt and reacting if it falls into the melt is a concern.

N A.15.3.3.1 Because of niobium’s strong affinity for oxygen and its tendency to become contaminated, niobium is melted under vacuum or inert gas using water-cooled copper crucibles to contain the molten metal. Partial vacuums are maintained by introduction of argon, helium, or mixtures of inert and reactive gases to the melting chamber.

Since the early 1950s, several titanium-melting furnaces have experienced explosions after water inadvertently entered the melting crucibles during the melting operation. Niobium and titanium both have a very high affinity for oxygen, which is one of the fundamental causes of melting furnace explosions. While there have been no reported niobium-melting furnace explosions, it is understood that the potential exists for an incident. Investigations of the titanium incidents have determined that the following three distinct events working together are responsible for melting furnace explosions:

- (1) Rapidly increasing pressure created by water making contact with the molten metal. This is the first phase of furnace explosions. The tremendous pressures generated can result in severe damage to the melting chamber and subsequent paths for the introduction of air into the chamber.
- (2) Reaction of the water with the molten niobium liberating hydrogen gas, the volume of which is dependent on the volume of molten metal in the crucible and the amount of water introduced. The generation of the hydrogen gas in itself does not produce a violent reaction or explosion but creates a potentially hazardous condition in the furnace chamber.
- (3) Introduction of air as a result of furnace vessel failure or by operation of valves, doors, or other equipment, which can result in an explosive mixture of hydrogen and oxygen. This explosive mixture can be ignited by the residual heat in the melting crucible.

The sequence of the events is thought to be as follows:

- (1) Steam explosion
- (2) Generation of hydrogen gas
- (3) Introduction of air into the chamber
- (4) Ignition/explosion of hydrogen–oxygen gas mixture

However, a steam explosion by itself can do severe damage, as would an explosion of a hydrogen–oxygen gas mixture. The explosion hazard is present in any niobium-melting furnace that uses water-cooled crucibles.

N A.15.3.3.3.1.1 Entrance of water into the furnace chamber is the primary cause of both steam and hydrogen explosions. Features to reduce or eliminate the entrance of water into the furnace chamber should be incorporated into the design of new equipment or modifications to older equipment. Examples are the use of sodium-potassium alloy (NaK) for cooling media, which has hazards of its own to consider. Newly created hazards should be weighed against the hazards potentially eliminated before incorporating the changes in practice.

N A.15.3.3.3.1.3 The furnace and crucible assembly should be located in a protective bunker that will direct the explosion away from operating personnel in adjacent areas. Isolation of the furnaces and remote operation remove the operating personnel from the immediate vicinity of the furnace and reduce the risk of severe injury if an explosion occurs.

N A.15.3.3.3.2.1 The explosion that can occur due to the rapid phase transformation (liquid to gas) of water trapped below molten metal takes place over a span of 10^{-5} seconds to 10^{-4} seconds. This time span is faster than a condensed phase detonation. The required pressure-relieving device would not be effective in relieving the rapid pressure buildup caused by the rapid transformation of water trapped below molten metal. The required device is intended to safely relieve only a much slower buildup of pressure, such as might occur from small incursions of water onto the surface of the molten metal.

N A.15.3.3.3.2.4 In vacuum arc remelting furnaces, arcing of the electrode to the mold wall is the primary cause of water being introduced into the chamber. To minimize the risk of arcing, the electrode should be straight and of uniform cross section to maintain the clearance between the electrode and the mold wall. Additionally, use of magnetic fields should be considered to deflect the arc away from the mold wall. Use of an electromagnetic field to contain the arc and to prevent arcing to the crucible is standard practice in vacuum arc remelting.

N A.15.3.3.3.2.5 Sudden rises in pressure are an indication of the onset of a steam or hydrogen–oxygen explosion in the furnace. The normal operating range and rates of rise in pressure for the process should be determined as part of the process control function. High-pressure and rate-of-rise-in-pressure interlocks should be installed to shut off the power to the process when they are activated. Continuation of heat to the process will continue the generation of molten niobium and result in more hydrogen or steam, or both.

The process operating parameters should be continuously monitored for abnormal conditions. Waterflow, temperature, and pressure on the cooling system are critical for maintaining the correct cooling conditions. Furnace pressure can provide early warning of abnormal conditions in the furnace chamber. Use of data acquisition to monitor the process is the most effective way to oversee the many parameters that could be of interest. Automatic alarms that warn operators of abnormal conditions are also beneficial. Where a parameter is deemed critical or an indicator of an extreme safety hazard, the use of interlocks to terminate the process is the best course of action.

N A.15.3.3.3.2.6 Hazards analyses can be used to determine the minimum thicknesses required for safe operation. Several cata-

strophic incidents have occurred due to failure to prevent the interaction between molten metals and water.

N A.15.3.3.3.3 The collection of moisture in a mold could cause the niobium to react, causing a fire or explosion.

N A.15.3.3.3.3.4 Locating control consoles away from the immediate vicinity of melting furnaces reduces the risk of injury if an explosion occurs. The distance from the furnace should be determined on a case-by-case basis by assessing the potential, magnitude, and expected path of the explosion. The best sources of technical expertise are the furnace manufacturers; they should consider the issue of remote location of control consoles for any new or modified niobium melting furnace.

N A.15.3.3.3.4 Furnace residues produced in a vacuum or inert gas atmosphere are finely divided powders that have not been exposed to an oxidizing atmosphere. Niobium has a high affinity for oxygen and will oxidize until a sufficiently thick oxide layer has formed. If the oxide layer is formed in a controlled manner, the process is called passivation. If the oxide layer is formed in an uncontrolled manner, it simply burns due to the exothermic nature of oxidation of niobium.

Condensed furnace residues, by nature, are extremely fine on the order of submicron size and will oxidize more rapidly and generate more heat than powders with large particle size distributions.

After the furnace has cooled to ambient temperature, the use of passivation cycles, in which controlled amounts of air are introduced into the furnace, will render the material stable. An alternative is to burn the material completely while it is contained in the furnace, followed by cooling to ambient temperature. Burning will result in the complete oxidation of the residue and eliminate the potential for further oxidation.

After passivation or burning of the furnace residues is completed, the material should be placed in covered drums and moved to a designated safe storage location.

N A.15.3.3.3.5 Loss of water supply to the crucible will result in a meltdown of the copper crucible and subsequently to the entry of water into the furnace chamber. If the normal water supply fails, an emergency water supply system should automatically be activated. Activation is best achieved with a low-water pressure interlock that activates the emergency water supply if the water pressure falls below a prescribed level.

N A.15.3.4.3.1 Because of tantalum's strong affinity for oxygen and its tendency to become contaminated, tantalum is melted under vacuum or inert gas using water-cooled copper crucibles to contain the molten metal. Partial vacuums are maintained by introduction of argon, helium, or mixtures of inert and reactive gases to the melting chamber.

Since the early 1950s, several titanium-melting furnaces have experienced explosions after water inadvertently entered the melting crucibles during the melting operation. Tantalum and titanium both have a very high affinity for oxygen, which is one of the fundamental causes of melting furnace explosions. While there have been no reported tantalum-melting furnace explosions, it is understood that the potential exists for an incident. Investigation of the tantalum incidents has determined that the following three distinct events working together are responsible for melting furnace explosions:

(1) Rapidly increasing pressure created by water making contact with the molten metal. This is the first phase of

furnace explosions. The tremendous pressures generated can result in severe damage to the melting chamber and subsequent paths for the introduction of air into the chamber.

- (2) Reaction of the water with the molten tantalum liberating hydrogen gas, the volume of which is dependent on the volume of molten metal in the crucible and the amount of water introduced. Generation of the hydrogen gas in itself does not produce a violent reaction or explosion but creates a potentially hazardous condition in the furnace chamber.
- (3) Introduction of air as a result of furnace vessel failure or by operation of valves, doors, or other equipment, which can result in an explosive mixture of hydrogen and oxygen. This explosive mixture can be ignited by the residual heat in the melting crucible.

The sequence of the events is thought to be as follows:

- (1) Steam explosion
- (2) Generation of hydrogen gas
- (3) Introduction of air into the chamber
- (4) Ignition and explosion of hydrogen–oxygen gas mixture

A steam explosion by itself can do severe damage, as can an explosion of a hydrogen–oxygen gas mixture. The explosion hazard is present in any tantalum-melting furnace that uses water-cooled copper crucibles.

N A.15.3.4.3.1.1 Entrance of water into the furnace chamber is the primary cause of both steam and hydrogen explosions. Features to reduce or eliminate the entrance of water into the furnace chamber should be incorporated into the design of new equipment or modifications to older equipment. Examples are the use of sodium-potassium alloy (NaK) for cooling media, which has hazards of its own to consider. Newly created hazards should be weighed against the hazards potentially eliminated before incorporating the changes in practice.

N A.15.3.4.3.1.3 The furnace and crucible assembly should be located in a protective bunker that will direct the explosion away from operating personnel in adjacent areas. Isolation of the furnaces and remote operation remove the operating personnel from the immediate vicinity of the furnace and reduce the risk of severe injury if an explosion occurs.

N A.15.3.4.3.2.1 The explosion that can occur due to the rapid phase transformation (liquid to gas) of water trapped below molten metal takes place over a span of 10^{-5} seconds to 10^{-4} seconds. This time span is faster than a condensed phase detonation. The required pressure-relieving device would not be effective in relieving the rapid pressure buildup caused by the rapid transformation of water trapped below molten metal. The required device is intended to safely relieve only a much slower buildup of pressure, such as might occur from small incursions of water onto the surface of the molten metal.

N A.15.3.4.3.2.4 In vacuum arc remelting furnaces, arcing of the electrode to the mold wall is the primary cause of water being introduced into the chamber. To minimize the risk of arcing, the electrode should be straight and of uniform cross section to maintain the clearance between the electrode and the mold wall. Additionally, use of magnetic fields should be considered to deflect the arc away from the mold wall. Use of an electromagnetic field to contain the arc and to prevent arcing to the crucible is standard practice in vacuum arc remelting.

N A.15.3.4.3.2.5 Sudden rises in pressure are an indication of the onset of a steam or hydrogen–oxygen explosion in the furnace. The normal operating range and rates of rise in pressure for the process should be determined as part of the process control function. High-pressure and rate-of-rise-in-pressure interlocks should be installed to shut off the power to the process when they are activated. Continuation of heat to the process will continue the generation of molten tantalum and result in more hydrogen or steam, or both.

The process operating parameters should be continuously monitored for abnormal conditions. Waterflow, temperature, and pressure on the cooling system are critical for maintaining the correct cooling conditions. Furnace pressure can provide early warning of abnormal conditions in the furnace chamber. Use of data acquisition to monitor the process is the most effective way to oversee the many parameters that could be of interest. Automatic alarms that warn operators of abnormal conditions are also beneficial. Where a parameter is deemed critical or an indicator of an extreme safety hazard, the use of interlocks to terminate the process is the best course of action.

N A.15.3.4.3.2.6 Hazards analyses can be used to determine the minimum thicknesses required for safe operation. Several catastrophic incidents have occurred due to failure to prevent the interaction between molten metals and water.

N A.15.3.4.3.3 The collection of moisture in a mold could cause tantalum to react, causing a fire or explosion.

N A.15.3.4.3.3.4 Locating control consoles away from the immediate vicinity of melting furnaces reduces the risk of injury if an explosion occurs. The distance from the furnace should be determined on a case-by-case basis by assessing the potential, magnitude, and expected path of the explosion. The best sources of technical expertise are the furnace manufacturers, which should consider the issue of remote location of control consoles for any new or modified tantalum melting furnace.

N A.15.3.4.3.4 Furnace residues produced in a vacuum or inert gas atmosphere are finely divided powders that have not been exposed to an oxidizing atmosphere. Tantalum has a high affinity for oxygen and will oxidize until a sufficiently thick oxide layer has formed. If the oxide layer is formed in a controlled manner, the process is called passivation. If the oxide layer is formed in an uncontrolled manner, it simply burns due to the exothermic nature of oxidation of tantalum.

Condensed furnace residues, by nature, are extremely fine on the order of submicron size and will oxidize more rapidly and generate more heat than powders with large particle size distributions.

After the furnace has cooled to ambient temperature, the use of passivation cycles, in which controlled amounts of air are introduced into the furnace, will render the material stable. An alternative is to burn the material completely while it is contained in the furnace, followed by cooling to ambient temperature. Burning will result in the complete oxidation of the residue and eliminate the potential for further oxidation.

After passivation or burning of the furnace residues is completed, the material should be placed in covered drums and moved to a designated safe storage location.

N A.15.3.4.3.5 Loss of water supply to the crucible will result in a meltdown of the copper crucible and subsequently to the entry of water into the furnace chamber. If the normal water supply

fails, an emergency water supply system should automatically be activated. Activation is best achieved with a low-water pressure interlock that activates the emergency water supply if the water pressure falls below a prescribed level.

A.15.4.2.1.4 Temperature-sensing elements connected to alarms or machine stop switches can be employed for locations where overheating of bearings or other elements is anticipated.

A.15.4.2.2.2 See NFPA 77.

A.15.4.2.2.3 Bearings located outside the air volume containing magnesium dust are preferred. Bearings within the air volume containing magnesium dust are potential sources of ignition in the event of a failure.

A.15.4.2.6.1.1 Special attention is necessary to ensure that the magnesium powder is not exposed to moisture.

A.15.4.3.2 The quantity of niobium powders stored in manufacturing operations and areas should be minimized. The quantity should be limited to that needed to continue the operation or process.

A.15.4.3.6.1 All but the coarsest niobium powders oxidize readily at temperatures above 80°C (176°F).

A.15.4.3.6.3 If inert atmosphere drying or vacuum drying are chosen as the most appropriate styles of drying, care must be taken to ensure that the niobium powder is cooled below 80°C (176°F) prior to re-exposing the powder to air atmosphere. Heated powder oxidizes at a high rate when exposed to air at elevated temperatures.

A.15.4.3.7 Care should be exercised in selection of the type of dryer used to dry niobium powders. Electric resistance element dryers should not be used due to the risk of niobium dust particles coming in contact with the heating elements and igniting. If dryers are outfitted with glass windows for the viewing of dryer contents, such windows should be covered with metal mesh reinforcement or external shielding to prevent the possibility of glass projectiles or other missile hazards resulting from an explosion. Dryer types include tray, drum, rotary, fluidized-bed, pneumatic, spray, and vacuum types.

Additionally, a hazards analysis should be conducted to determine the safest method of drying based on the specific materials to be dried. Fine surface-area niobium powders are very sensitive to self-heating. Coarse-particle-size niobium powders are much less sensitive to drying conditions. Drying parameters — both the type of drying and the specific conditions of drying [i.e., temperature, bed height, drying gas atmosphere (air atmosphere or inert gas)] — need to be assessed in light of the specific powders to be dried.

A.15.4.3.7.3 Consideration should be given to a hazard analysis for a wet collection system installation.

A.15.4.3.7.6 Dryer control systems are critical components that provide safety during drying operations. The reliability of the microprocessor controllers should be checked and inspected on a regular basis (e.g., daily or weekly). Temperature overshoots can result in dangerous conditions that might allow dryer chamber temperatures to exceed 80°C (176°F). The reliability of thermocouples and fan controls should also be inspected on a regular basis to ensure correct and safe operation.

A.15.4.3.7.8(5) When niobium powder is dried in atmospheres containing oxygen, it is recommended that the dryer be outfitted with a means to allow the introduction of an inerting agent. Because niobium powder undergoes, under certain conditions, a highly exothermic reaction with nitrogen, nitrogen is not an appropriate inerting agent. The inerting agent of choice is argon or helium. Because of dryer design and configuration, it is sometimes difficult and awkward to use other appropriate extinguishing materials in the event of a niobium dryer fire. Historically the use of argon gas in extinguishing a niobium fire has proven to be very effective.

A.15.4.3.12.1 Controlling the generation and accumulation of niobium fugitive dust is of critical importance, owing to the specific nature of niobium metal powders. The minimum explosible concentration (MEC) for certain niobium powders (high surface area) is very low, and the K_{st} values can be very high. For those reasons, controlling and preventing dust clouds of niobium powder are important in preventing the possibility of a deflagration.

A.15.4.3.12.4 Refer to NFPA 77.

A.15.4.3.12.7 The presence of moisture in air reduces surface resistivity of many materials in process areas where niobium powders are handled, thereby reducing general electrostatic discharge (ESD) ignition risk.

A.15.4.3.14.1 Explosion venting is especially important for combustible niobium dust, due to the high maximum explosion pressures reached and the extremely high rate of pressure rise. For information on the design of explosion vents and predicting the size of the fireball, see NFPA 68. Dust collectors, when provided by a manufacturer, seldom have properly sized venting to handle a combustible niobium dust explosion.

In processes where the component part consists of a variety of materials and it is not possible to segregate the combustible metal component during the finishing process, it should be noted that this mix of metals presents an additional hazard in the process ventilation equipment. Daily inspection, cleaning, and general maintenance of the system must be performed to minimize exposure to inherent risks when performing finishing procedures on these types of parts. All equipment should be bonded and grounded in accordance with NFPA 77.

A.15.4.3.14.2(2) Where deflagration venting is used, its design should be based on information contained in NFPA 68. For deflagration relief venting through ducts, consideration should be given to the reduction in deflagration venting efficiency caused by the ducts. The length of the relief duct should be restricted to not more than 6 m (20 ft).

A.15.4.3.14.2(3) Ductwork provided with explosion isolation systems identified in NFPA 69, which can prevent propagation of a deflagration into other parts of the process, is not subject to NFPA 68.

A.15.4.3.14.2(5) This method is limited in effectiveness because of the high concentrations of inert material required and the potential for separation during handling. Other methods are preferred.

A.15.4.3.15 The use of inert gas for all machinery is highly recommended. All typical operations encountered in the processing of tantalum powder produce ignition sources (mechanical friction, impact sparks, hot surfaces, and potentially electrostatic discharge). As such, the primary basis of

safety should be the exclusion of oxygen from the atmosphere under which niobium powder is processed.

N A.15.4.3.16.2 Where personnel are working on suitable anti-static or conductive flooring, they should be wearing appropriate footwear. Footwear having resistance in the range of 1×10^6 ohms to 1×10^8 ohms is considered to be antistatic. Generally, it is recommended that personnel limit the conductivity of their footwear to the range of 5×10^4 ohms to 1×10^8 ohms. This accomplishes grounding of static discharge from the operator but reduces the potential risk of electrocution. All personnel should be electrically grounded when they are working in an environment containing a material possessing an MEC of 100 mJ or less.

N A.15.4.3.16.5 Unauthorized personnel should not be permitted in powder-handling areas. Identifying authorized personnel is determined by the individual company. Authorized personnel are people experienced and knowledgeable in hazards associated with niobium powders. The intent of the requirement is to prevent people who are not familiar with the hazards associated with niobium powders from wandering through a production area. This requirement does not preclude such a person from being escorted by authorized personnel.

N A.15.4.4.1.1 The sensitivity of tantalum powder to ignition through contact with hot surfaces or exposure to hot environments, while in an oxygen-containing environment such as air, is directly proportional to the surface area of the tantalum powder. Even low-surface-area tantalum powders are sensitive to exposure in air to hot environments. Historically, it has been determined that tantalum powders should not be exposed to atmospheres containing oxygen at temperatures above 80°C (176°F). Above that temperature, even passivated tantalum powders are shown to continue to oxidize. Intermediate- and high-surface tantalum powders should not be exposed to hot surfaces at 80°C (176°F). Lower temperatures should be employed.

N A.15.4.4.1.4 Care should be exercised in selection of the type of dryer used to dry tantalum powders. Electric resistance-element dryers should not be used due to the risk of tantalum dust particles coming in contact with the heating elements and igniting. If dryers are outfitted with glass windows for viewing of dryer contents, such windows should be covered with metal mesh reinforcement or external shielding to prevent the possibility of glass projectiles if a tantalum dust cloud explodes. Dryers include tray, drum, rotary, fluidized-bed, pneumatic, spray, and vacuum types.

N A.15.4.4.1.4.8 Dryer control systems are critical components that provide safety during drying operations. The reliability of microprocessor controllers should be checked and inspected on a regular basis (such as daily, weekly). Temperature overshoots can result in dangerous conditions, which might allow dryer chamber temperatures to exceed 80°C (176°F). The reliability of thermocouples and fan controls should also be inspected on a regular basis to ensure correct and safe operation.

N A.15.4.4.1.4.10 When tantalum powder is dried in atmospheres containing oxygen, it is recommended that the dryer be outfitted with a means to allow the introduction of an inerting agent. Because tantalum powder undergoes, under certain conditions, a highly exothermic reaction with nitrogen, nitrogen is not an appropriate inerting agent. The inerting agent of choice is argon or helium. Because of dryer design and configuration, it is sometimes difficult and awkward to use other appropriate extinguishing materials in the event of a tantalum dryer fire. Historically, the use of argon gas in extinguishing a tantalum fire has proven to be very effective.

uration, it is sometimes difficult and awkward to use other appropriate extinguishing materials in the event of a tantalum dryer fire. Historically, the use of argon gas in extinguishing a tantalum fire has proven to be very effective.

N A.15.4.4.2.2 The quantity of tantalum powders stored in manufacturing operations and areas should be limited to that needed to continue the operation or process.

N A.15.4.4.2.8 Refer to discussion under A.15.4.4.1.1.

N A.15.4.4.2.9.1 A means to determine protection requirements should be based on a risk evaluation, with consideration given to the size of the equipment, consequences of fire or explosion, combustible properties and ignition sensitivity of the material, combustible concentration, and recognized potential ignition sources. See AIChE, "Guidelines for Hazard Evaluation Procedures."

The following items are areas of concern during the design and installation of process equipment:

- (1) Elimination of friction by use of detectors for slipping belts, temperature supervision of moving or impacted surfaces, and so forth
- (2) Pressure resistance or maximum pressure containment capability and pressure-relieving capabilities of the machinery or process equipment and the building or room
- (3) Proper classification of electrical equipment for the area and conditions
- (4) Proper alignment and mounting to minimize or eliminate vibration and overheated bearings
- (5) Use of electrically conductive belting, low-speed belts, and short center drives as a means of reducing static electricity accumulation
- (6) When power is transmitted to apparatus within the processing room by a belt or chain, the belt or chain should be encased in a practically dust tight enclosure, constructed of substantial, noncombustible material that should be maintained under positive air pressure. Where power is transmitted by means of shafts, the shafts should pass through close-fitting shaft holes in walls or partitions.

N A.15.4.4.2.9.2(2) Where deflagration venting is used, its design should be based on information contained in NFPA 68. For deflagration relief venting through ducts, consideration should be given to the reduction in deflagration venting efficiency caused by the ducts. The length of the relief duct should be restricted to not more than 6 m (20 ft).

N A.15.4.4.2.9.2(5) This method is limited in its effectiveness due to the high concentrations of inert material required and the potential for separation during handling. Other methods are preferred.

N A.15.4.4.2.10 The use of inert gas for all machinery is highly recommended. All typical operations encountered in the processing of tantalum powder produce ignition sources (mechanical friction, impact sparks, hot surfaces, and potentially electrostatic discharge). As such, the primary basis of safety should be the exclusion of oxygen from the atmosphere under which tantalum powder is processed.

N A.15.4.4.2.11.2 Where personnel are working on suitable anti-static or conductive flooring, they should be wearing appropriate footwear. Footwear having resistance in the range of 1×10^6 ohms to 1×10^8 ohms is considered to be antistatic. Generally, it is recommended that personnel limit the conductivity of

their footwear to the range of 5×10^4 ohms to 1×10^8 ohms. This range accomplishes grounding of static discharge from the operator but reduces the potential risk of electrocution. All personnel should be electrically grounded when they are working in an environment containing a material possessing an MIE of 100 mJ or less.

A.15.4.4.2.11.5 Unauthorized personnel should not be permitted in powder-handling areas. Identifying authorized personnel is a decision made by individual companies. Authorized personnel are persons experienced and knowledgeable in hazards associated with tantalum powders. The intent of the requirement is to prevent persons who are not familiar with the hazards associated with tantalum powders from wandering through a production area. This requirement does not preclude such a person from being escorted by authorized personnel.

A.15.5.1.3 Certain non-dusting grades of aluminum flake powder are being produced. These powders tend to reduce the hazard of inadvertently caused dust clouds. They are as combustible as regular grades of flake powder and, once levitated into a cloud, exhibit the same explosibility characteristics. For those reasons, the same precautions must be observed as for normal grades of powder.

A.15.5.3.4 Static-dissipating flooring is often employed in niobium manufacturing and processing plants. However, it is recognized that it is difficult to maintain the conductivity of the floor over a period of time using currently available methods. Careful examination of the details of this standard will disclose the logic of the use of conductive flooring materials.

The surface of a static-dissipating floor will provide a path of moderate electrical conductivity between all persons and portable equipment making contact with the floor, thus preventing the accumulation of dangerous static electric charges.

The maximum resistance of a static-dissipating floor is usually less than 10^6 ohms, as measured between two electrodes placed 0.9 m (3 ft) apart at any points on the floor. The minimum resistance is usually greater than 2.5×10^4 ohms, as measured between a ground connection and an electrode placed at any location on the floor. This minimum resistance value provides protection for personnel against electric shocks. Resistance values are checked at regular intervals, usually once each month.

Refer to *NFPA 70* for equipment and procedures that are acceptable practice for testing for minimum and maximum resistance. Measurements should be made at five or more locations in each room, and results can be averaged.

For compliance with the maximum resistance limit, the average of all measurements should be less than 10^6 ohms.

For compliance with the minimum resistance limit, one individual measurement should be less than 10^5 ohms, and the average of not fewer than five measurements should be greater than 2.5×10^4 ohms.

Where resistance to ground is measured, two measurements are customarily made at each location, with the test leads interchanged at the instruments between the two measurements. The average of the two measurements is taken as the resistance to ground at that location. Measurements are customarily taken with the electrode or electrodes more than 0.9 m (3 ft) from any ground connection or grounded object resting on the

floor. If resistance changes appreciably with time during a measurement, the value observed after the voltage has been applied for about 5 minutes can be considered the measured value.

A.15.5.3.5 The following are considered spark resistant and appropriate for use with niobium:

- (1) Beryllium-copper
- (2) Brass
- (3) Phosphorous bronze

Aluminum should not be used because of the potential for thermite sparks. Thermite sparks can occur with aluminum, magnesium, tantalum, titanium, or their alloys in the presence of oxygen carriers such as iron or lead oxide. Thermite sparks are highly incandescive (and energetic) sparks that are white hot.

In the manufacture of product from niobium powder, it might be necessary to mix the niobium powder with other additives or to pour the niobium powder from one container to another. Both of these operations tend to produce a niobium dust cloud. A hazards analysis should be done on any operation that produces a dust cloud.

If the dust cloud causes any dust to accumulate on surrounding surfaces, personnel performing the operations should be wearing flame-retardant clothing, wearing antistatic shoes, and standing on antistatic floor covering or antistatic floor mats.

If the ventilation or exhaust system is sufficient to prevent dust accumulation in the operator's work area, flame-retardant clothing will not be necessary. However, antistatic footwear, static dissipative floor covering, or both should be used.

A.15.5.3.7 See the discussion under A.15.5.3.4.

A.15.5.3.7.8 Compacted niobium powder, when heat treated under argon or a vacuum, behaves in a similar fashion to niobium powder. When heat treated, the passivated oxide film present on the surface of each niobium particle comprising the compact diffuses into the center of each particle.

On removal from the heat treatment furnace, the passivated oxide film should be re-established through exposure to air. Because the oxidation of niobium generates heat, it is important that the temperature of the compact is below 50°C (122°F) when the compact is exposed to air. This practice prevents the re-oxidation of the compact from proceeding at such a rate that the compact becomes too hot. If the compact becomes too hot, a risk of ignition and fire will exist. Separating the trays of compacts further reduces the risk by providing uniform exposure to air and prevents localized hot spots from developing. It is essential to ensure that all niobium particle surfaces become re-oxidized prior to further processing of the heat-treated niobium compacts.

A.15.5.4.1.1 Any time a combustible dust is processed or handled, a potential for explosion exists. The degree of explosion hazard will vary, depending on the type of combustible dust and processing methods used.

A.15.5.4.1.3 Static-dissipative flooring is often employed in tantalum manufacturing and processing plants, although it is recognized that it is difficult to maintain the conductivity of the floor over a period of time using currently available methods. Careful examination of the details of this standard will disclose the logic of the use of conductive flooring materials.

The surface of a static-dissipative floor will provide a path of moderate electrical conductivity between all persons and portable equipment making contact with the floor, thus preventing the accumulation of dangerous static electric charges. The maximum resistance of a static-dissipative floor is usually less than 10^6 ohms, as measured between two electrodes placed 0.9 m (3 ft) apart at any points on the floor. The minimum resistance is usually greater than 2.5×10^4 ohms, as measured between a ground connection and an electrode placed at any location on the floor. This minimum resistance value provides protection for personnel against electric shocks. Resistance values should be checked at regular intervals, usually once each month.

Refer to *NFPA 70* for equipment and procedures that are acceptable practice for testing for minimum and maximum resistance. Measurements should be made at five or more locations in each room, and the results can be averaged.

For compliance with the maximum resistance limit, the average of all measurements should be less than 10^6 ohms.

For compliance with the minimum resistance limit, one individual measurement should be less than 10^5 ohms, and the average of not less than five measurements should be greater than 2.5×10^4 ohms.

Where resistance to ground is measured, two measurements are customarily made at each location, with the test leads interchanged at the instruments between the two measurements. The average of the two measurements is taken as the resistance to grounds at that location. Measurements are customarily taken with the electrode or electrodes more than 0.9 m (3 ft) from any ground connection or grounded object resting on the floor. If resistance changes appreciably with time during a measurement, the value observed after the voltage has been applied for about 5 minutes can be considered the measured value.

N A.15.5.4.1.4 Personnel handling tantalum powder in a procedure that causes the generation of tantalum dust should wear flame-resistant or flame-retardant clothing.

Flame-resistant clothing does not ignite, because the fibers themselves do not support combustion. Flame-retardant clothing consists of a base material, such as cotton, that is treated with a topical chemical additive to make the fabric resist ignition and to make it self-extinguishing. When a flame touches the clothing, the coating initiates a series of chemical reactions, creating gases to extinguish the flame.

The difference between flame-resistant and flame-retardant clothing is the permanency of the flame resistance. With flame-resistant fibers, the properties are permanent; with flame-retardant fibers, the properties can be laundered out unless specific procedures are followed.

Either fiber will allow a few seconds for the employee to react and escape. Pure cotton and wool, while they are considered flame retardant, are not appropriate for protection from tantalum fires, because either will allow the accumulation of tantalum dust within the fiber structure.

N A.15.5.4.1.5 The following are considered spark resistant and appropriate for use with tantalum:

- (1) Beryllium-copper
- (2) Brass
- (3) Phosphorous bronze

Aluminum should not be used because of the potential for thermite sparks. Thermite sparks can occur with aluminum, magnesium, tantalum, or titanium or their alloys in the presence of oxygen carriers such as iron or lead oxide. Thermite sparks are highly incendiary (and energetic) sparks that are white hot.

N A.15.5.4.3.1 In the manufacture of product from tantalum powder, it might be necessary to mix the tantalum powder with other additives or to pour the tantalum powder from one container to another. Both of these operations tend to produce tantalum dust clouds. A hazards analysis should be done on any operation that produces a dust cloud. If the dust cloud causes any dust to accumulate on surrounding surfaces, personnel performing these operations should wear flame-retardant clothing, wear antistatic shoes, and stand on antistatic floor covering or antistatic floor mats. If the ventilation or exhaust system is sufficient to prevent dust accumulation in the operator's work area, flame-retardant clothing will not be necessary. However, antistatic footwear, static dissipative floor covering, or both should be used.

N A.15.5.4.4.1 See the discussion under A.15.4.4.1.1.

N A.15.5.4.6 See A.15.5.4.3.1.

N A.15.5.4.8 Compacted tantalum powder, when heat treated under argon or vacuum, behaves in a similar fashion to tantalum powder. When heat treated, the passive oxide film present on the surface of each tantalum particle making up the compact diffuses into the center of each particle.

On removal from the heat treatment furnace, the passive oxide film needs to be re-established through exposure to air. Because the oxidation of tantalum generates heat, it is important that the temperature of the compact is below 50°C (122°F) when the compact is exposed to air. This practice prevents the reoxidation of the compact from proceeding at such a rate that the compact becomes too hot. If the compact becomes too hot, a risk of ignition and fire exists. Separating the trays of compacts further reduces the risk by providing uniform exposure to air and prevents localized hot spots from developing. It is essential to ensure that all tantalum particle surfaces become reoxidized prior to further processing of the heat-treated tantalum compacts.

N A.15.5.4.8.1 Tantalum compacts after furnacing might also require passivation.

N A.15.6.1.1 Dispersions of metals in organic solvents present special concerns. In addition to the water reactivity/pyrophoricity due to the reactive metal, solvents present the concerns of flammable or combustible liquids and vapors. The SDS provided by the supplier of the material, NFPA 30, and NFPA 77 are applicable to addressing the problems of combustible liquids and vapors.

N A.15.6.2.2 This requirement is applicable to stamp mortars, mills, fans, and conveyors in all areas where dust is produced or handled, such as in finishing and polishing equipment, filters, driers, dust screens, fixed storage bins, and dust collection and transport systems of all types. For further information on bonding and grounding, see NFPA 77.

N A.15.6.2.4 When metal is milled in a ball or rod or similar type of mill in the presence of a liquid that is chemically inert with respect to the metal, the air-dust explosion hazard is eliminated. When the resulting product is subsequently exposed to air,